JAN 9 1931

Heating · Piping and Air Conditioning

IN THIS ISSUE

Articles on

Heating—
By S. A. McGUIRE *and* A. McCAWLEY

Piping—
By PAUL R. UNGER *and* KALMAN STEINER

Air Conditioning—
By R. C. DOREMUS *and* JAMES W. COX JR.

Journal Section
of A. S. H. V. E.

JANUARY, 1931

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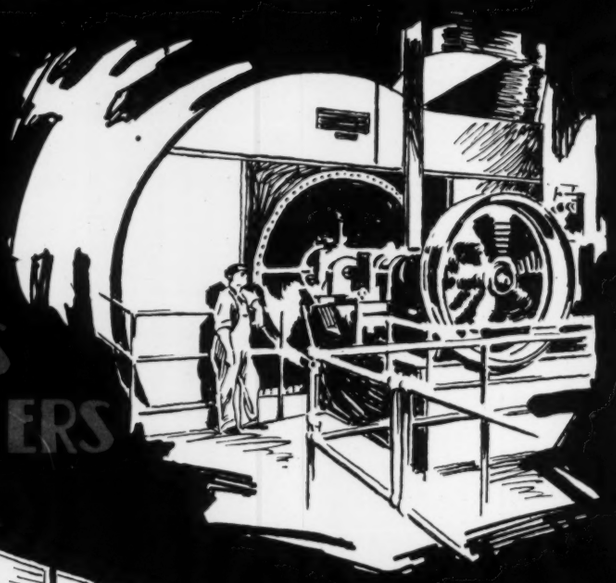

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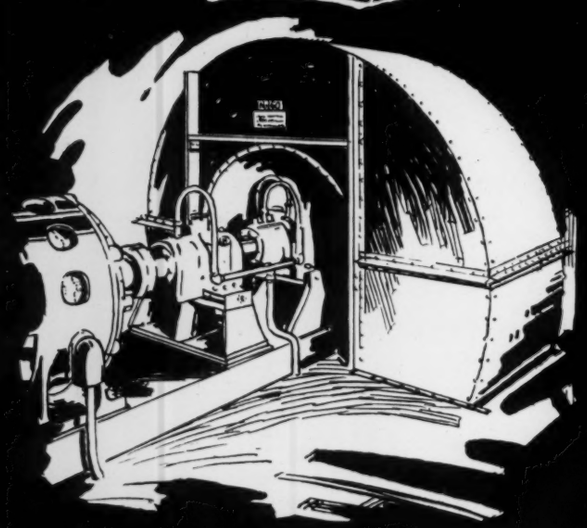

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The EDITOR'S PAGE

Heating · Piping and Air Conditioning

FROM ARTICLES IN THIS ISSUE

"The engineer should adopt some scheme or systematic schedule in performing the overhaul of air cooling equipment and, naturally, this brings up the points of what do to and where to begin."—*R. C. Doremus.*

"In view of the fact that a high pressure valve may be completely ruined by a single cut or scratch across the valve seat, the users of the valves should employ care in handling them."—*J. J. Harman.*

"A reasonable standardization of word usage in an industry is of particular value."—*"Open for Discussion."*

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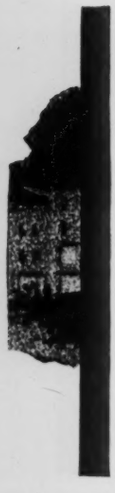

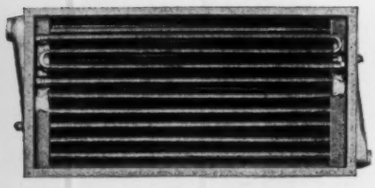

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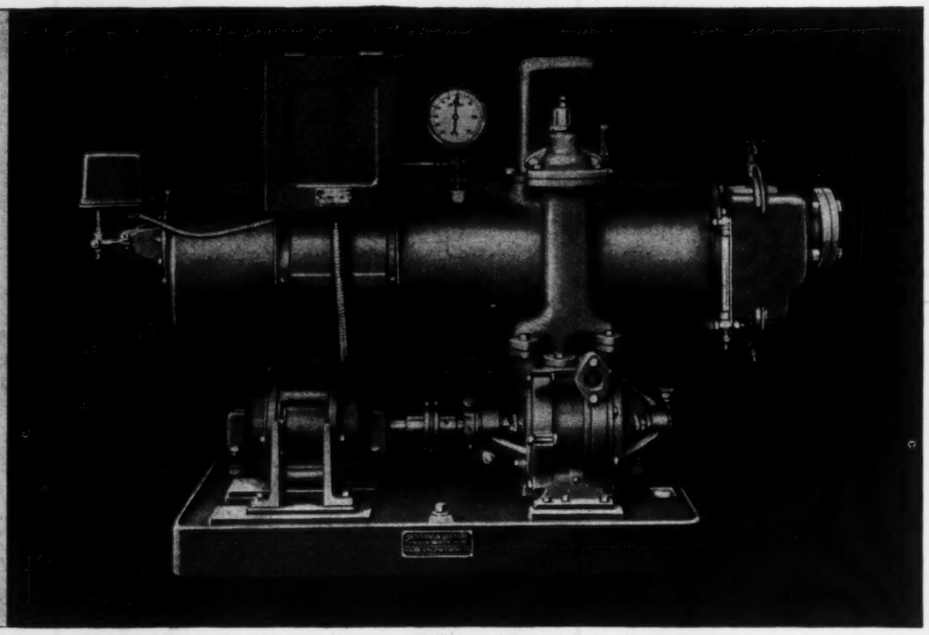


Heating · Piping and Air Conditioning

Vol. III January, 1931 No. 1

Now Is the Time to Overhaul Air Cooling and Refrigerating Equipment

By R. C. Doremus*

EVERY AIR cooling plant comprises an arrangement of piping and equipment particularly designed for a specific purpose. Regardless of size, it represents an investment from which fairly continuous and efficient service is expected and demanded. Many such plants naturally have their peak loads during warmer months of the year and are able to shut down in the colder months. Some others are combined with heating and air conditioning plants in providing proper atmospheric conditions for all seasons, and their peaks are fluctuating but fairly continuous. A third group is vital to manufacturing or storage processes which must be maintained in continuous operation with little or no shutdown. In cases of continuous duty, duplicate equipment is usually provided to permit operation with one set of equipment, while the duplicate is held in reserve for alternate or emergency use, thus permitting a shutdown while repairs and overhauling are done.

Necessity of Overhauling

No equipment, however well designed or perfectly made, can indefinitely resist wear and corrosion and a periodic overhaul, comprising cleaning up, inspection, tuning up, replacement, adjustment, painting, etc., is necessary to insure its continuous use and operation.

The vital importance and necessity of overhauling air cooling equipment is self-evident and universally realized by engineers operating any kind of mechanical apparatus. It is doubly important with air equipment on account of the greater corrosion hazard and the continuity of service required and is, therefore, a most essential step in the operating engineer's schedule just as are the items in his routine of operations. Quite often, engineers of refrigerating plants realize its value too late to accomplish the overhauling in a thorough and systematic manner on account of the approach of the operating season, when sudden demands require them to skim the surface and do the abbreviated job in a rush. Consequent breakdowns usually occur at a most inopportune time and cost more in time, parts, expense, and interruption in operating schedule and production or spoilage than several overhauls properly and conscientiously done.

Systematic Schedule Needed

The engineer should adopt some scheme or systematic schedule to follow in performing the overhaul and, naturally, this brings up the points of what to do and where to begin. If he is a wide-awake operator, he has made notes (written or mental) during the operating season of troubles encountered and overcome; leaks in valves, pipe and fittings, fits and clearances in pumps and compressors, defects in devices and equipment and conditions which have reduced operating capacity or economy or caused unusual care. Possibly he has made some temporary maintenance repair, knows of some gaskets or bolts that need replacing to avoid a blowout or shutdown or of some electrical difficulty that does not appear to be serious, but is, nevertheless, disconcerting. Many such items are invisible as long as the equipment is operating, but show up like a sore thumb

* George B. Bright Co., refrigerating engineers and architects, Detroit, Mich.

The efficient operating engineer keeps the equipment under his charge in good condition; a periodic overhaul is one of the best methods of securing continuous service at the minimum cost.

as soon as it stops. Notations of these points give the engineer a clear cut picture of what to concentrate on, what needs inspection, repair or replacement.

As soon as the shutdown period occurs, the engineer should review his notes on these troublesome items, inspect all essential parts of the plant in order to analyze the true operating condition of the equipment and determine what is to be done to bring it up to its highest point of efficiency and reliability for the coming season —and then do it. In this way, a methodical plan is scheduled and he is ready to consider the details of the job. Without such a plan, it is too easy to court trouble by overlooking the true condition of a piece of equipment as long as it runs.

A Schedule of Overhaul Items

A suitable brief or schedule of items should be made, noting anything needing special attention; this will serve not only as a guide but may be used as a tally sheet on which each item may be checked off as it is given attention. It is most important to make notations of particular items passed as satisfactory, but which will probably need special attention at the next overhaul, or of clearances or items that seem peculiarly characteristic of the particular piece of equipment:

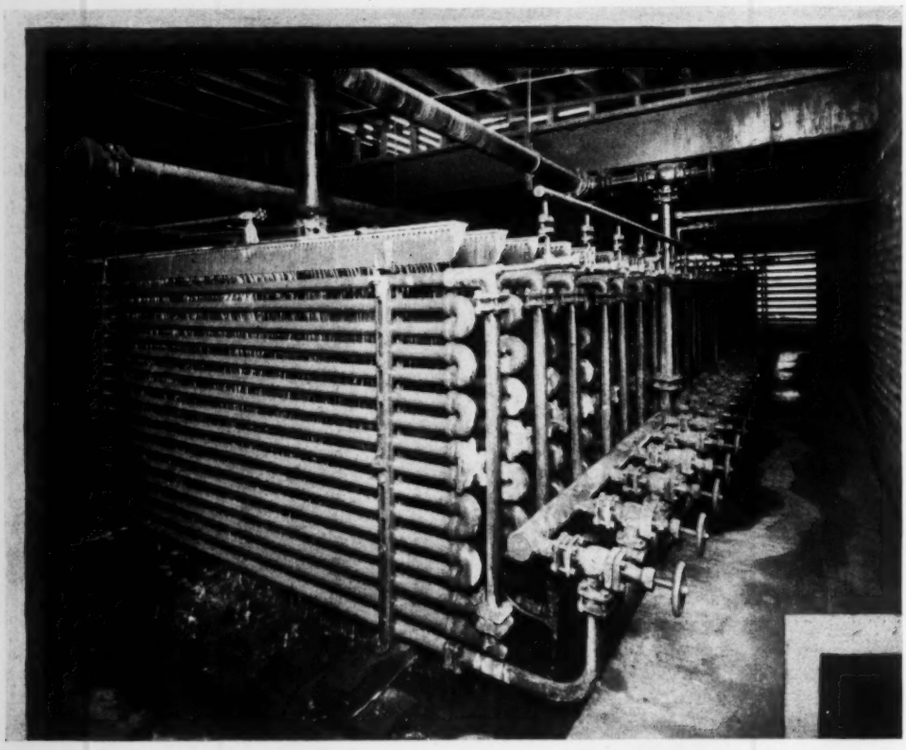
1. *Compressor:* Suction, discharge and safety valves, dismantle piston and rings, cylinder wall, clearances, stuffing box and packing, piston rod, crosshead, connecting rod, crankshaft, pins, bearings, gaps, lubrication, adjustments, cleaning and painting.
2. *Oil, liquid and scale traps:* Clean out, drain, test joints, clean up and paint.
3. *Condensers:* Clean inside and outside, drain, test joints and paint.
4. *Receiver:* Drain oil, repack gage glass cocks, clean glass and install new packing, clean up and paint.
5. *Direct expansion piping:* Pump out liquid, pump back, drain oil, test valves, pipe, fittings clean outside and paint.

Now is the time when the load on many air cooling and refrigeration plants in factories, office buildings, hotels, hospitals, theaters and other structures is light. It is a good time to check the system thoroughly.

6. *Brine piping:* Drain brine, test alkalinity, treat brine, clean strainer, flush out sediment, install brine, clean piping, test for leaks and paint.
7. *Water piping:* Drain, flush piping, clean strainers and nozzles, clean, test for leaks and paint.
8. *Pumps:* Dismantle, impellers, seal rings, bushings, bearings, clean, reassemble and paint.
9. *Refrigerant:* Check quantity, charge more if necessary.
10. *Pipe covering and insulation:* Examine, repair and paint.
11. *Instruments:* Thermometers, gages, recorders, thermostatic controls, alarms and cut-outs. Inspect and calibrate all.
12. *Electrical equipment:* Switchboard, panel boxes, motors, starters, clean and paint.

The Compressor

It is well to give first consideration to the major items of equipment and the minor items can follow, or be



A Battery of Counter - Flow Atmospheric Condensers

sandwiched in between. In any refrigerating system, the compressor is probably the most vital part, and since it contains the majority of moving parts it is quite liable to develop defects sooner than other parts of the system. The remainder of the plant may be in only good or fair shape and the system still do fairly good work, but if the compressors are in bad shape or stop altogether, the refrigerating system ceases to function.

There are a number of items to be checked when the compressor is operating, such as the action of compressor valves, packing, piston rod or crankshaft, crossheads, connecting rod, fly wheel, lubrication, etc., and these should be observed carefully in order to detect anything abnormal. In a large plant it is quite helpful to *indicate* the compressor to show the operation of valves and piston rings for this will assist in ferreting out any troubles when these items are inspected.

After this has been done, the compressor should be stopped and taken apart in order to thoroughly examine

How to do it — and what to do about it — is told here —

each part subject to wear, for no inspection can be made from the outside appearance of the machine, except of the paint job.

Suction and Discharge Valves

The suction and discharge valves, which are so important to efficient compressor operations, should be removed, taken apart and examined closely. Spring tension should be checked and adjusted for quiet operation. The valves should be ground to a tight, perfect seat, and if the seat between the valve cage and cylinder head is not perfect, as shown by a discoloration or deposit, it should be ground to a perfect seat. Badly worn valves or springs should be replaced rather than to take any chances on a shutdown for replacement later.

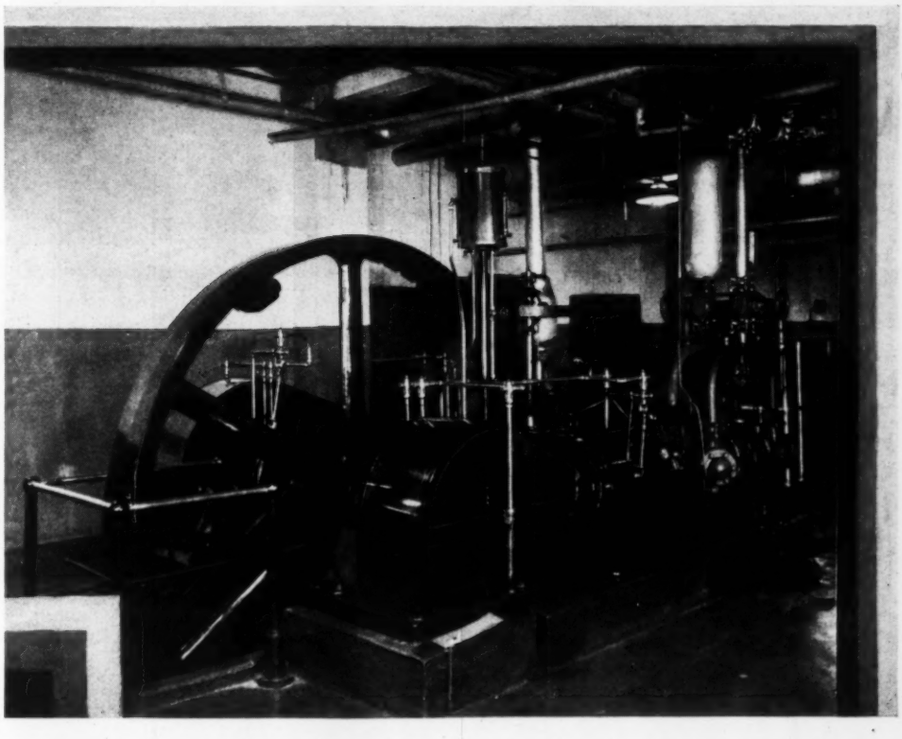
Safety Head

If the compressor is of the vertical type, it is equipped with a spring loaded safety head. The tension of the spring should be checked as the head is removed by compressing it several times with the head while the safety head is in place. The safety head cylinder seat should be examined for leaks just as the valves, for in reality it forms one large discharge valve. It should be ground to a good seat if necessary, and, at least, all dirt, scale or grit should be removed. Care should be taken in handling the safety head not to mar the seat, for an imperfect seat or leak from any cause will make a continual loss in displacement of each stroke.

The water jackets should be cleaned and flushed out with water.

Clearances Should be Checked

While the valves are out, the piston end clearances at each end can be checked by turning the shaft once slowly and compressing thin strips of solder or wire. The heads should then be removed, taking care not to injure the gaskets. The cylinder wall should be highly polished and examined for score marks or signs of excessive wear. The piston side, top and bottom clearances should be checked at different points of the stroke with hardwood strips or feeler thickness gages. If the clearance varies to any great extent it should be carefully double-checked with a pin gage. Reboring the cylinder may not be necessary; in fact, it should not be required ordinarily more often than every three or four years with medium speed machines; but it is far better to rebore when necessary than to lose displacement and power until it is done. If the cylinder is rebored, a new piston



A 25-Ton Ammonia Compressor in a Refrigerating Plant

will also need to be obtained and fitted to take care of the larger bore.

The Piston Rings

The piston rings should receive a very careful scrutiny. If they are only slightly worn, they may be increased in diameter to give a better tension against the cylinder wall by hammering them on the inside with light taps of a ball pein hammer. If they are badly worn, fit loosely in ring grooves or show other defects, they should be replaced. All rings, whether new or old, should have a slightly turned edge to avoid scoring the cylinder or wiping off too much oil from the wall. Their action in the ring grooves should be fairly tight and yet free from sticking. In trunk pistons, the vent should be inspected to see that it is open.

The Piston Rod and Packing

The piston rod should be examined for score marks, excessive wear throughout the stroke or shoulders at the ends of the stroke. If it does not show excessive wear it should be satisfactory and it is best to let it alone. If it does show a noticeable wear, it should be turned down to a smaller diameter to clean up the marks and reground. In case the rod is turned down very much, say 1/32 in. or more, attention should be paid to the stuffing box lantern and the cylinder head bushing. If they are of the inside babbitted type, they may be rebabbitted to fit the new rod size, otherwise new ones should be installed to proper size.

Failure to observe these precautions will cause the packing to shred through the annular space into the cylinder, which may cause undue heating of the rod even to scoring and is bound to spoil the packing in short time. Some compressors are furnished with no bushings in the cylinder head, in which case a seal or wiper ring at least 3/8 in. thick may be placed next to the head to avoid the loss of packing. While this is out, it is well to check the rod and bushing for alignment. If the bushing is loose, it should be aligned and tightened for a loose bushing will cause an annoying slap that is often hard to find. If the machine is old, with a worn cylinder and the rod is out of alignment, eccentric rings will be needed to compensate in the stuffing box. The grade, type and make of packing used should be determined by the nature of compressor operation, but the choice is naturally left to the engineer's discretion inasmuch as he is responsible for its care, operation, lubrication and adjustment.

Crosshead and Guides May Need Attention

The crosshead and guides should then be examined. Any excessive wear on the guides indicated by slight shoulders should be smoothed out by a scraper. The shoes may need rebabbitting, although they have considerable adjustment to compensate for wear. The wedges should be adjusted to take up any loose play caused by wear on either the shoes or guides. The connecting rod pin and crank pin should be examined for wear and adjusted to operate with no knocks. It may be necessary to rebabbitt the pin boxes, in which case they should be scraped and oil grooves cut in the right direction. Note whether your machine is running *over* or *under* and cut oil grooves in boxes and adjust crosshead shoes accordingly. If it is running *over,* the thrust on both head and crank end strokes will be upward from the upper shoe to the guide, and if running *under,* it will be downward from the lower shoe to the guide.

The main crankshaft bearings should be examined for wear and rebabbitted, scraped and grooved if necessary. Wedge adjustments may be shimmed to avoid this if wear is only slight. In scraping all bearings, a 70 per cent ground is considered satisfactory, for they will wear to a true shape and polished surface.

Care of the Motor

If the compressor is driven by a direct-connected synchronous motor, the bearing adjustment should be inspected by inserting feeler thickness gages in the gap between the rotor and stator. Too close a spacing may cause a resonance hum, and if it is too close at bottom, it may even cause the motor to *freeze* due to the magnetic pull. The gap varies with different makes of synchronous motors, but whatever the total gap may be, it should be evenly divided at the sides and less at the top than at the bottom so that the shaft is 10 per cent above the center of the stator opening to compensate for the magnetic pull and prevent freezing at the time of starting.

Reassembling the Compressor

In reassembling the compressor, care should be taken to see that the piston rod runs true from end to end, and that the piston and clearances are correct for quiet operation. If the packing has been properly blown out or carefully picked out without damage, it may be reused; however, if it has been damaged in being removed or if the rod dimensions have been changed, new packing should be used. New gaskets should be used. The cap screws on all valve cages should be screwed in snugly so they will not work loose in operation. All adjustments should be made with care and the compressor turned over by hand to test clearances before being operated electrically.

If the discharge safety pop valve has been leaking due to a previous blow, it probably has not reseated itself tightly and should be removed and tightly seated at the bench.

If the compressor is a vertical type, the oil in the crankcase should be withdrawn and the bottom of the case carefully cleaned of all dirt, scale, sand and grit. A certain amount of this is bound to pass the screen in the scale trap and some sand will probably be loosened up continually in the crankcase casting by the oil and vibration. Therefore, the case should be thoroughly cleaned out and a new charge of oil installed, not only within a week of starting the new compressor but also at each periodic overhaul period.

After the compressor has been reassembled, following the careful inspection outlined above, it can be put in service for another season without much fear of an unexpected shutdown. As a final touch, it should be cleaned up and painted, if desired.

Oil, Liquid and Scale Traps

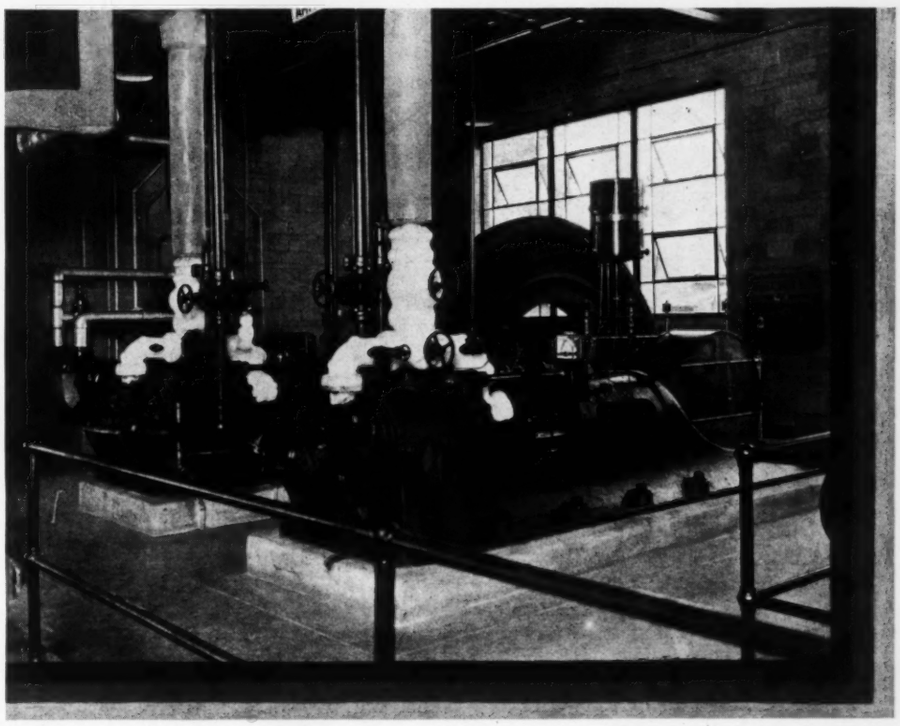
The discharge oil trap has been separating oil from the discharge vapor and undoubtedly has been drained periodically as occasion demands. It should be drained again, cleaned of dirt or scale, cleaned outside and may

be painted with a heat and weather resisting paint if desired.

The suction liquid separator should be pumped out, heated by pumping back to thaw out any grease deposits, and blown out. It is equally or more important to thaw out any grease and oil that may have collected in the recirculating liquid line and blow it out, especially if this line is trapped for a gas seal as will be found in so many plants. If this is not done, the line may be plugged with grease and fail to function in recirculating liquid to the evaporator, which will cause the compressor to run *wet* with a consequent loss in displacement due to re-expansion.

The scale trap has trapped an accumulation of dirt, scale and "what have you" from the low side, depending on the age of the plant and scale conditions on the inside of the evaporator and the piping. It should be thoroughly cleaned out, the screen removed and cleaned with gasoline and reassembled. Any obstruction to the free passage of gas at this point will cause the compressor to operate either longer than necessary or at a lower back pressure, either of which means a loss in displacement and power.

A Direct - Connected, Synchronous Motor-Driven Ammonia Compressor



Care of Condensers

The condensers are probably next in importance to the compressors. Essentially, they form a heat transfer apparatus used in removing the refrigerating and compressive heats in liquefying the discharge gas, and must be clean to function as designed. Their capacity will be curtailed by a covering of oil, scale or foreign matter which is bound to collect (on account of their function) on both sides of the heat transfer surface.

If they are of the atmospheric type, they should be blown down and cleaned inside. The exterior surface should be cleaned of scale deposits, dirt and corrosion and carefully examined for leaks, tapped with a pein hammer for thin walls and new pipe installed if necessary.

If they are of the double pipe, tubular or shell type, their treatment should be quite similar. All heads or bends should be removed and water gaskets discarded. The inside of the tubes should be thoroughly cleaned with an approved scale cutter and brushed out with wire brush. In some waters, the tubes will pit, especially with high oxygen or air content, and they should be examined by feeling ends and by looking through the tubes toward a light. New tubes may be required in six to eight years or even sooner in some cases. All tubes and joints in tube sheets should be tested for leaks and tubes rerolled in tube sheets as may be required.

All heads and water return bends should be reassembled and furnished with new gaskets. The shells should be cleaned inside and outside and painted, if desired. If you wish to be doubly sure there are no tube leaks, pump up some refrigerant into the condensers with the tubes filled with water but none flowing. Allow it to stand for several hours and then withdraw some water and test it for presence of refrigerant by the approved method for the refrigerant used. This will indicate whether any refrigerant has leaked through splits, pin holes or tube beads into the water and will often show up a leak where a superficial inspection would miss it. Also, there have been occasions where a condenser tube would hold tight when scaled but would leak after the scale was removed; this makes such a test very desirable.

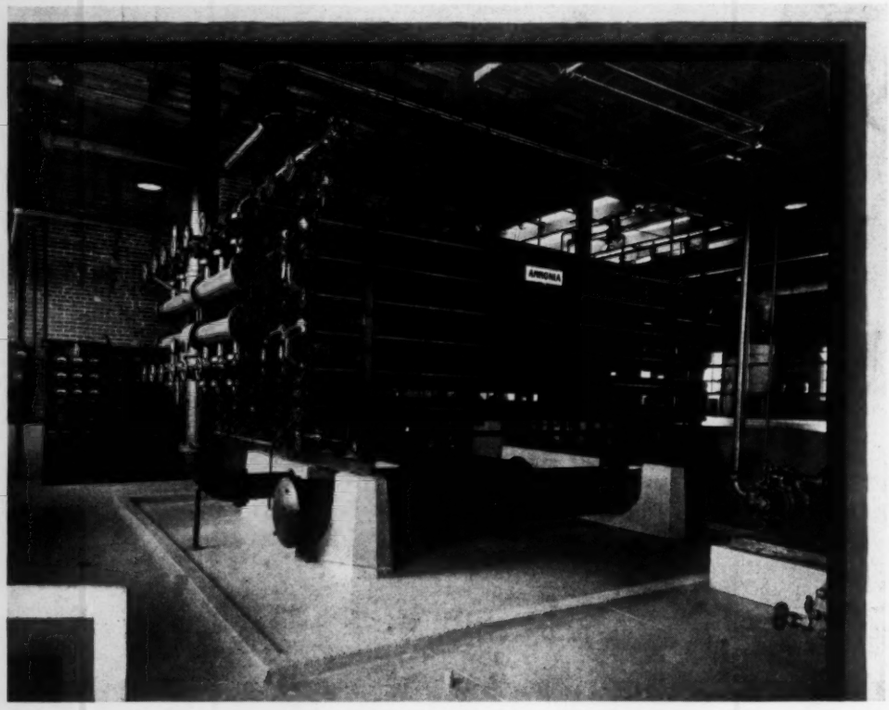
Regardless of the type of condenser used, the surfaces should be maintained as clean as possible to operate at an economically low head pressure to avoid abnormally high power costs. All condensers overhauled should be

well cleaned outside, tested for gas and water leaks and painted with a good rust resisting paint to arrest corrosion.

If the condenser used is of the atmospheric type, the last thing to do is to level up the troughs for even water distribution so that the whole surface may be available for condensing vapor. An uneven water distribution is shown by fluctuations at different points in the temperature of the water. A clogged condenser stand in a large battery is easily noticed by a difference in temperature of the condenser pipe just above the liquid line, and should be blown out with steam and drained of water, while still warm, and dried by air.

In closed types of condensers, the even distribution of water is equally as important and can be obtained easily by valve adjustment.

The condensers should finally be purged of all air admitted during the overhauling process so that they are in condition for another season's operation.



A Tubular Type Ammonia Condenser Battery and Liquid Receiver

The Receiver

The liquid receiver is simply a storage tank for a stock of refrigerant, but it should be examined closely inasmuch as it is a major item of the plant equipment. Oil should be drained from it and, if an air test of 250 to 300 pounds is being put on the condenser, it is well to drain the liquid from the receiver, pump it out and test it along with the condensers. The gage glass and cocks should be repacked to insure tightness. Finally, the shell should be cleaned and painted along with the condenser.

Direct Expansion Piping

The evaporator of a refrigerating plant is equally as important as the condenser, whether it be of pipe coil or shell cooler types, for the refrigeration produced involves the transfer of a certain amount of heat through the surface comprising the evaporator. Its capacity for doing this work depends to a great extent upon the condition of the outside and inside of this surface. Any accumulation of snow, frost or ice on the outside, or of grease, oil, scale or rust on the inside, simply serves to insulate the surface against heat transfer, decreasing its capacity and thus defeating its purpose. Inasmuch as the total area of the surface remains constant, the compressor must produce a greater temperature difference by running at a lower back pressure to produce the same amount of work and, of course, this causes a penalty in power.

There are different methods used in defrosting. If the evaporator is in air, the accumulation is easily removed by closing the liquid expansion valve and admitting or pumping back hot discharge gas into the evaporator. This is satisfactory for pipe, but should *not* be done with shell apparatus inasmuch as the pressure attained will exceed the allowable working pressure which would blow the pop valve or tend to rupture the vessel. Another means is to shut the evaporator suction valve and open the expansion valve, allowing the heat of the liquid to thaw it off. As soon as it is loose, it can be rapped off, for it no longer adheres to the evaporator. If the evaporator is submerged in a bath of brine or water, either method may be used and the ice will thaw loose and can be rapped off so that it will float. In some cases it is permissible and faster to allow the bath to warm up sufficiently to do the job.

In any case, the coating should be removed from the surface whether it be inside or outside. In order to remove the accumulation of grease, oil, rust and scale from the inside, the evaporator should be drained of oil and refrigerant, and, if very bad, blown out with steam and drained of water while still warm, and dried out by blow-

ing air through it. Some engineers object to putting steam and air into an evaporator, in which case the heat may be applied externally by steam or blow torch, or heating the brine with steam, and the accumulator blown down by refrigerant. The operator may need to use a gas mask in the latter method, for considerable refrigerant escapes during this process. Local canditions will determine the best procedure to be followed.

When the cleaning is done, all pipe, valves and fittings should be examined for leaks with air pressure and soap-suds, or by submergence if located in a tank. A coating of paint or rust-resistive material is advisable to arrest corrosion, especially in a water cooler. The evaporator should then be pumped out, exhausting the air and foul gases. It is then ready for another season.

Brine Piping

Wherever a brine system is used, the piping, valves and fittings are subject to corrosion. This will be rapid in brines containing air as in an open system, and is more so with sodium than calcium brines. Corrosion may also be due to electrolysis or to acidity.

Acidity of the Brine

The acidity or alkalinity of the brine should be tested and the *pH* value determined by chemical indicators. It is well to maintain the brine slightly on the alkaline side of neutrality, in which case the *pH* value should be in the range from 7.0 to 9.0. If the brine is new, it is likely to be very alkaline, and this can be decreased by adding the proper amount of muriatic acid or CO_2 gas. If it is too acid, it may be neutralized and made slightly alkaline by the addition of caustic soda or lime in the right amount. If this is inserted in the brine tank in a burlap bag in fair circulation or agitation too much will not be added, for it can be withdrawn when a sufficient quantity has been dissolved into the brine.

The piping should be drained and all sediment flushed out with water. The strainer screen should be removed and thoroughly cleaned and replaced. All exposed piping, valves and fittings should be cleaned with a wire brush, tested tight and painted to retard corrosion.

Water Piping

All circulating water piping should be drained and flushed out with water to be sure it is clean. All nozzles and strainers should be removed and blown out with water or air and replaced. The piping system should be examined for leaks and tightened up. All exposed valves, pipe and fittings should be cleaned well and painted to protect both pipe and thread joints from corrosion.

Brine and Water Pumps

The brine and water pumps are probably called on for more continuous service than any other item of equipment in the plant, and as long as they run they are liable to be overlooked. If time in the overhauling schedule permits, these pumps should be dismantled for a careful inspection. The impellers should be examined for corrosion, for they will gradually wear to a smaller diameter, lowering the capacity head.

The seal rings and bushings should be inspected for wear and clearances and any badly worn parts replaced. The shafts in stuffing boxes should be looked over for wear and if badly scored by grit or packing they should be put in a lathe and turned up smooth. If the cuts are too deep to clean up, it is better to discard the pump shaft and install a new one. New packing should be installed and the oiling of bearings observed. The pumps should be reassembled and tried out to be sure they are in readiness for operation and, finally, both pumps and bases painted.

Refrigerant

Every plant must have sufficient refrigerant in the evaporators for proper operation and enough in the receiver to give a safe liquid seal. The quantity in the system should be checked and replenished by an additional charge, as may be necessary.

Pipe Covering and Insulation

All pipe covering and insulation, no matter how well installed, is subject to a gradual deterioration. Therefore, the overhaul period offers a good opportunity to examine it, repair it where necessary and paint the outside. A good grade of waterproof paint should be used every two years whether it appears to need it or not, for this is the safest guarantee of a long insulation life.

Indicating and Recording Instruments

All indicating and recording thermometers should be checked occasionally in a pan of broken ice and water to see that they read properly, and, if not, the necessary corrections should be noted.

All indicating and recording gages should be checked on a dead weight tester to see that their calibrations are correct; if not, they should be reset or calibrated.

The thermostatic controls, alarms, cut-outs and similar relays can easily be checked for setting and operation to see that they are in readiness for the coming season.

Fans

Some air cooling systems depend on temperature gravity circulation, such as the direct systems, but generally fans are used for circulation, such as in the indirect system. In cases where fans are used, the suction pipe collar should be removed and the blast wheel examined for general condition. In some cases it will be found heavily crusted with dirt or even lint and in other cases it might be simply rusted by natural corrosion. In any case the blades of the wheel, as well as the arms forming the spider, should be scraped to remove any such accumulation; this is especially important with fans running over 500 r.p.m., to avoid an out-of-balance condition. In any case, the liberal use of a wire brush and a coat of paint will serve to lengthen the life of the fan if it is located where corrosion is excessive.

The fans are usually operated continuously and little thought is given to their condition until a break-down occurs; therefore they should be carefully examined each overhaul period, including their bearings and drive, to insure a continuity of operation during the next season.

Electrical Equipment

The amount of electrical overhauling to be done depends on the amount of equipment and the troubles encountered during the season. In the usual small- or

medium-sized plant a general inspection should be made of the switchboard, panel boxes, motors and starters. All control equipment should be cleaned up if corroded and arcing tips replaced if burned. All motors should be blown out with air and painted with a spray coat of waterproof insulating varnish.

Bearings should be inspected for oiling and, if slightly rough, can be scraped. All oil and sediment in sleeve bearings or grease in ball bearings should be cleaned out and washed with gasoline or carbon tetrachloride and the lubricant replaced. Frequent observation of this detail will lengthen the life of the equipment.

Gaps between rotors and stators should be gaged and adjusted. Commutators should be smooth and clean and if arcing on account of score marks the commutator should be turned down to clean up the marks and all mica insulation properly undercut. At the same time, brushes and springs are replaced if badly worn.

The 4th Heating and Ventilating Congress at Brussels

By A. Beaurrienne

Zone Control

BEFORE the last *Congress* in 1927, André Nessi spoke on the computation of heat quantities necessary to heat a building with variable inside temperatures in the course of a 24-hour day, the calorific capacity of the building being the basis of the calculation.

Taking as a basis the "Influence Method," described in a recent book he published in collaboration with Mr. Nissolle (graphical methods to calculate heating installations giving variable temperatures during a same day) Mr. Nessi explained the graphic solution of the following general problem, the data being:

1) The inside temperature curve to be realized.
2) The outside temperature curve to be considered.
3) The physical coefficients (specific heat, density, radiation and convection coefficients) of the materials constituting the inside and outside walls.

The problem is to draw the heat output curve, that is, the curve of the heat quantity to supply the building, to get the inside temperature curve corresponding to the outside temperature curve. Mr. Nessi described a mechanical calculating apparatus and gave several applications for it.

This apparatus includes a cinematic system acting on a planimeter which draws a curve, giving at any moment the coefficient by which the normal heat losses calculated for constant inside and outside temperatures must be multiplied to get the instantaneous output of the heating system.

Mr. Nessi named this coefficient the *virtual* gradient, the real gradient being the difference between the inside and outside temperatures at the considered moment.

This method of studying heating systems, giving variable temperatures during a day, is the result of precise graphical methods grounded on an analytical study of the physical phenomena involved.

The method depends on the two following rules:

1) For an inside and an outside temperature curve, there is one heat output curve and only one.
2) The data of the problem must take care of an initial state, which may be generally determined from the temperature curves during the preceding days, this number of days varying with the calorific capacity of the building.

Mr. Nessi applied his theories to show the use of zoning the heating systems of buildings.

High Pressure

The writer, president of the *Congress* and a member of the *A. S. H. V. E.*, proposed to search in actual scientific and physical knowledge for those elements which may be the basis for future evolution of heating systems.

He considered the transportation of heat to a great distance and summarized briefly the properties of steam under very high pressures, to the critical point (3,150 lb., 707 F).

He reminded his hearers that the total heat quantity necessary to produce one pound of saturated steam increases with the pressure, when this pressure remains lower than 420 pounds per square inch (at this pressure, it is about 1198 Btu) but decreases when the pressure becomes over 420 pounds; at the critical point, the total heat is only 917 Btu.

Take steam at the critical point in a pipe; the friction will produce a loss of pressure and even if the pipe is perfectly protected against cooling as the pound of steam at reduced pressure contains more Btu's, condensation will occur.

Experience has shown that the specific heat of steam under these pressures is as high as 2.8 that of water. Owing to this property a superheat of about 100 F will be sufficient to allow leaving steam to contain heat enough to prevent condensation.

The writer said that, from a thermal point of view, the transportation of 400 million Btu to a distance of six miles could be realized with a heat loss not exceeding 3 per cent.

From the metallurgical point of view such pipes are not actually practicable, he said. Special but very expensive steels would be strong enough to withstand such pressures, but the greatest difficulty would be to allow for expansion and contraction.

Radiant Heat

Considering the utilization of heat, the writer brought to the attention of the *Congress* the effective temperature such as it has been defined by the *A. S. H. V. E.*

He said that radiant heat is an element which must be considered in comfort. In winter, in a country covered with snow and receiving radiation from the sun, if there is no wind, one may feel comfortable though the thermometer, protected against this radiation, indicates a very low temperature.

He stated that if a man was in a room heated by a radiant ceiling, and all the other walls were reflectors, he would receive direct and reflected heating rays on all parts of his body and would have the sensation of being in a 70-degree atmosphere, though the thermometer indicated a lower temperature.

If the radiating ceiling had a very small calorific inertia, the effect of temperature would be felt as soon as the heating system was put in operation.

FIG. 1—THE BOILER ROOM. *A*, ROTARY TYPE BURNERS OF 200 HP. EACH; *B*, OIL METERS; *C*, PRESSURESTAT

Piping Oil for Industrial Processes

By Paul R. Unger* and Kalman Steiner*

THIS article deals with oil storage and oil piping in a typical industrial plant that uses oil fuel for heating, for process steam and in direct-fired industrial furnace work.

The plant is that of the Indestro Manufacturing Company, located in the Central Manufacturing district of Chicago. The following equipment in the plant uses oil for fuel:

Three 72 in. x 16 ft. HRT Boilers, rated at 125 hp. each.
Four forges.
Six cyanide furnaces.
One lead bath.
One heat treating furnace.

It is obvious, at the outset, that the diverse nature of the oil fired equipment necessitates the use of several different types of oil burners. In the present case, the boilers are used for low pressure radiation, high pressure unit heaters, and for high pressure process work in the plating department, etc. Horizontal rotary burners were selected for the boilers. The furnaces are all fired with low pressure air atomizing burners because of the size of the furnaces and the shapes of the combustion chambers.

Oil Storage

Since the plant is located in a manufacturing district with switch track and railroad siding, provisions were made for the purchase of oil in carloads. Oil tank cars in use today are usually of either 8,000 or 10,000 gallon capacity. A 15,000 gallon storage tank was therefore furnished, allowing room for a carload of oil with at least 5,000 gallons reserve storage. The tank, which is 8 ft. in diameter by 40 ft. long, is built of 5/16 in. steel throughout, riveted and welded. It is buried underground alongside the boiler room, about 30 ft. from the siding and is anchored with tie rods and turnbuckles to a concrete slab underneath it, the slab being 42 ft. x 10 ft. x 2 ft. thick, which was calculated to be heavy enough to keep the tank from floating under any conditions. To insure accessibility, the tank was equipped with a 16-in. bolted manhole, built up to grade with a 24 in. concrete well, topped with a heavy sewer cover. Along the center line at the top of the tank are the following openings:

One 3 in. for fill line from tank cars.
One 2 in. for fill line from tank wagon.
One 2 in. for vent line.
One 2 in. for suction line.
One 2 in. for return line.
One 2 in. for measuring line.

Mild steel galvanized pipe was used throughout, with screwed malleable fittings and screwed brass gate and check valves.

The tank car fill line (3 in.) is run from the top of the tank, which is 24 in. below grade, underground to the siding, terminating alongside the track with a screwed cap. Inasmuch as it would be impractical to attempt a rigid connection between the 3-in. pipe and the car opening, fifteen feet of all-metal flexible hose was furnished, screwing into the fill line on the one end and provided with a union nut fitting on the other end for connection to the opening on the bottom of the car, thus using gravity to empty the car of oil into the storage tank. There are times, however, when it is not possible to unload a car by gravity. When the oil must be pumped from the car, an overhead unloading rack is provided

* Johnson Oil Burner Company, Chicago.

with swing joints so that a suction pipe can be dropped through the manhole opening of the car. An oil pump of 90 g.p.m. capacity then unloads the car of 10,000 gallons in approximately two hours.

Fuel oil equipment in a plant of this size usually burns a fuel of 18 to 20-degree Baume gravity or heavier. This means that in extremely cold weather unloading, especially by gravity, will be difficult unless the fuel is heated. For this reason, in regions where necessary, all oil tank cars are equipped with steam coils. A steam line should therefore be provided for introducing steam into the coils of the tank cars. With high pressure steam, a 1½ in. line is adequate; with low pressure steam the line should be 2 in. Flexible hose is also needed for this connection. The condensate is either wasted to the ground or returned to the system.

An auxiliary 2-in. fill line to the tank was run underground from the nearest street, so that if necessary, oil could be obtained on short notice in tank wagons. This insures against a plant shut-down due to railroad delays in oil shipments.

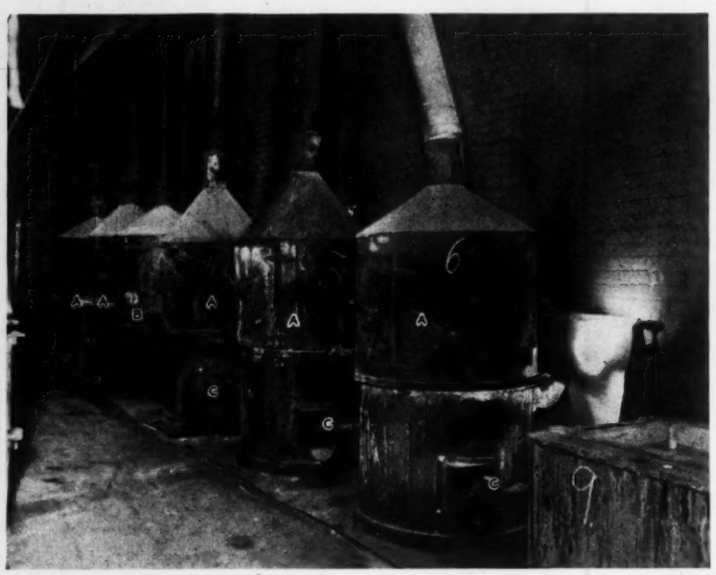


FIG. 2 — THE CYANIDE ROOM. *A*, CYANIDE FURNACES; *B*, LEAD BATHS; *C*, NOZZLE TYPE OIL BURNERS

The vent line from the tank terminates on the outside wall of the building in a double turned-down copper-screened ell. A 2-in. line is also brought from the tank straight up to grade with a flush cap on top, for measuring the oil content. For convenience, an oil gage calibrated in gallons was mounted on the boiler room wall.

The hydrostatic element for the indicating wall gage is introduced into the tank by drilling a small hole, about ¼ in. in diameter, through the top. The hydrostatic bulb, attached to the end of a copper tubing, is slipped through the hole and lowered to the bottom of the tank, through the oil body. A quantity of air is thus trapped in the bulb. The hydrostatic pressure acting on this trapped air is transmitted through the tubing to the indicating device on the boiler room wall. Naturally, as the oil level rises and falls in the tank, due to filling and withdrawal, the variations in pressure are relayed to the indicator, which is calibrated to read directly in gallons of oil. The copper tubing from the tank to the gage is run in ½-in. conduit.

Inside Piping

Suction and return lines, each 2-in., were brought from the tank through the boiler room wall to the oil pumps. The suction line begins at a point about 6 in. above the bottom to allow a clearance for the accumulations of sludge and heavy ends that gradually settle out of the fuel over a long period of operation. In some cases a foot valve, or vertical check valve, is placed at the lower end of the suction stub to prevent back flow of oil from the suction pipe when the pumps are not running. With a tight suction line, however, and a good dependable pump, the foot valve should not be needed to hold the suction line and pump primed. In this plant, where heavy oils are handled, it was thought that in time the heavy settlings might impair the free operation of the poppet of a foot valve resulting in interrupted oil flow. A better plan than the foot valve, if it is felt that a check of some kind must be used, is a special angle check directly over the tank where the suction line drops into the tank opening. This valve is accessible in case it must be reached for cleaning.

Needless to say, the suction line should be as short and direct as possible with all unnecessary elbows and bends eliminated.

The return line is screwed into the top of the tank. In some instances where the number of openings in a tank is limited, the return is brought into the side opening of a 2-in. tee placed over the tank flange, the other opening of the tee taking a nipple which rises to grade for the measuring line.

Duplicate Strainers

Before reaching the oil pumps, as it comes over in the suction line, the oil passes through oil strainers. These strainers are of the basket type, having a 32-wire mesh cloth. Duplicate strainers should always be used and so piped that one may be cleaned while the other is in use, avoiding a shut down.

Pumping the Oil

Through the oil strainers the oil reaches the pumps. Two oil pumps are employed, each of sufficient capacity to handle a quantity reasonably in excess of the maximum plant demand. The pumps used are of the direct motor-driven rotary impeller type. The pumps being run at constant speed, while the amount of oil being used varies, the return line is needed to carry back the excess oil pumped. In the present case the pumps were driven with 1 hp. motors and have a capacity of 500 gallons per hour each.

Leaving the pump, the oil passes in a 2-in. pressure line through an oil preheater, where its temperature is raised to the most efficient operating point. This heater is of the copper U-tube type, the oil passing through the tubes, and the steam, at 100 lb. pressure, passing through the shell around the tubes. The condensate is ejected through a trap and sent into the boiler return main.

With most oils of heavy gravity, the most efficient operating temperature is about 170 F. This temperature is maintained by controlling the steam admission to the heater through a bellows operated steam valve, the bellows actuated by a bulb immersed in the hot oil body and connected through flexible tubing. While these oil preheaters are of the same general type as domestic hot water heaters, the coils through which the oil passes usually are built of a special sulphur resisting alloy such as admiralty metal. The gaskets are copper woven asbestos.

The hot oil leaves the heater in a 2-in. line covered with 2-in. air cell magnesia blocks, part of it to be consumed in the basement in the three boilers, the remainder to pass upstairs to the forge and furnace rooms. The hot oil line divides close to the boilers, continuing 2-in. up through the basement ceiling and into the process rooms, and sending off a 1½-in. branch over the boilers. From this branch, 1-in. feeders drop down to each boiler and burner.

As before mentioned, horizontal rotary burners were installed on the boilers. Each burner is equipped with a 2 hp. air-cooled motor. This motor drives a solid steel shaft to which are keyed the fan and oil atomizer.

Choice of Piping System

If the reader will examine, even superficially, the oil piping layout as shown in the diagrammatic outline, he will immediately note the length of hot oil piping from the heater to the most distant forge and furnace—a distance of several hundred feet. The necessity of conveying the heated oil this distance gave rise to the consideration of several alternatives during the original design of the plant. It will be noted that the actual piping scheme used is of the simple one-pipe, non-return type, which means that a *dead end* occurs at the most distant point from the heater. While this arrangement is, of course, inexpensive from an installation standpoint, the question of design was whether it would not be better to use a return line, to give a recirculating system of hot oil distribution.

Such a system of recirculation has in its favor the fact that it would insure a constant supply of hot oil to any of the burners, at any time a piece of equipment might be placed in use. It would also eliminate any possibility of formation of carbon deposits by stagnant flow. Finally, it tends to equalize oil temperatures throughout the system. Obviously, these three conditions are essential to an installation of automatic equipment, where an oil-burning device may suddenly be thrown into operation without attention from a plant worker. Satisfactory control in automatic equipment is predicated upon uniform flow and unfailing ignition, which are reflected in uniform temperature, viscosity and sediment content of the fuel.

In the present case, however, we are dealing with only direct manual control apparatus (except that the boilers are under semi-automatic control on a high-low principle), the operators always igniting the burners by hand and setting the fires to suit the needs of the immediate process. The decision, therefore, was in favor of the non-recirculating system, as it was the consensus of opinion that the extra cost of the recirculating pipe and valves would not have been justified by the plant conditions. In addition, the recirculating system would have involved the heat loss by the long return line of warm oil, the additional capacity required in the size of the preheater, and additional steam consumption in the preheater. All things considered, therefore, the choice of the one-pipe layout was warranted in this case.

As mentioned above, the 2-in. hot oil line, after sending its 1½-in. branch to the boilers, continues upward and over to the process furnaces. The further distribution is clearly shown in the layout sketch. The forges

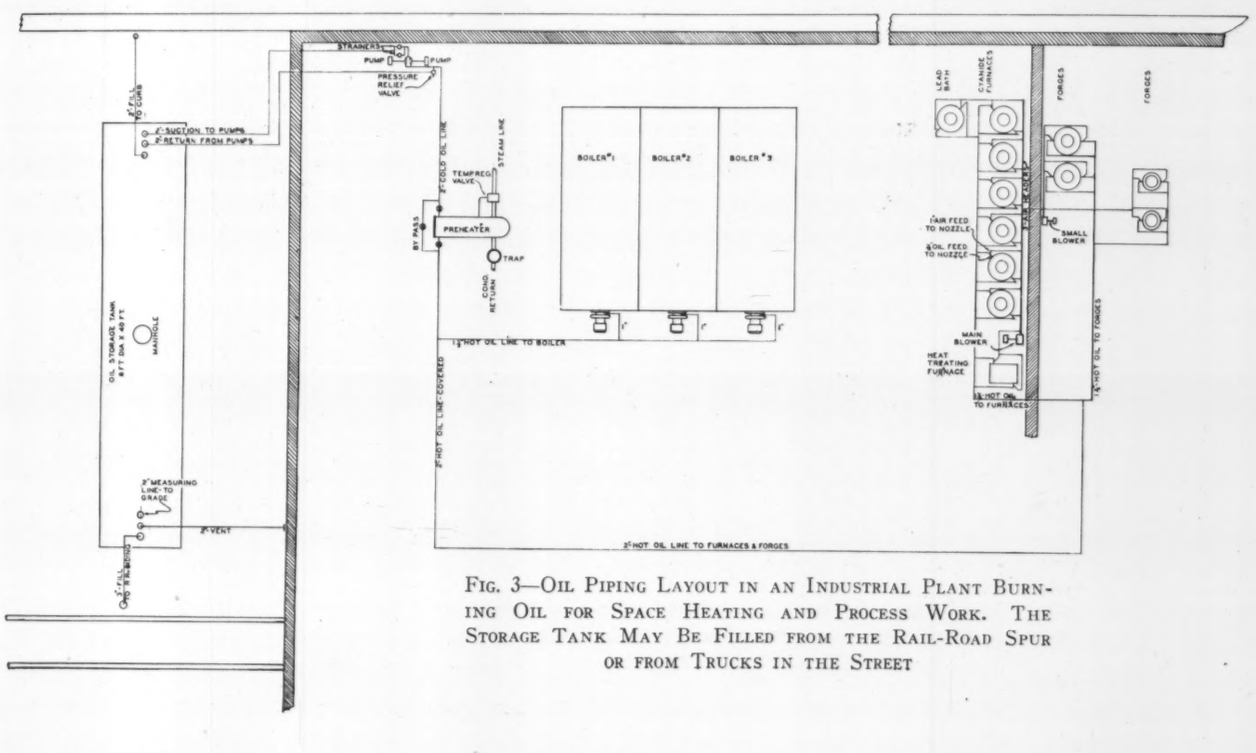


FIG. 3—OIL PIPING LAYOUT IN AN INDUSTRIAL PLANT BURNING OIL FOR SPACE HEATING AND PROCESS WORK. THE STORAGE TANK MAY BE FILLED FROM THE RAIL-ROAD SPUR OR FROM TRUCKS IN THE STREET

and furnaces are equipped with two burners each, each burner having a range of from ½ gallon to 10 gallons per hour. As the distribution system spreads out, the pipe sizes are gradually reduced to the burner entrance size of ½ in.

Air Piping

There is in the plant a total of twenty-four nozzles on forges, cyanides, lead baths and tempering furnaces. Low pressure air is used on the forges and furnaces to effect atomization of the fuel in the nozzle burners. Eight to twelve ounces pressure is sufficient for this purpose. Each nozzle requires about 50 cubic feet of primary air per minute at maximum load. While, under ordinary plant operation, all twenty-four nozzles would not be likely to be in use at the same time, it was necessary to design not alone for the maximum load of these twenty-four, but also to provide an excess capacity in the air supply for additional equipment if needed and installed as the plant expanded. Referring again to the diagram, a centrifugal blower, driven by a 7½ hp. motor, is shown supplying air into a 3-in. header. There was also provided an auxiliary blower, driven by a 5 hp. motor, in the forge room, sized to handle the forges only, on occasions when they alone were in use. This arrangement of course effects an economy in power consumption.

Determination of Pipe Sizes

In the foregoing discussion, oil pipe sizes have been mentioned as varying from 2 in. down to ½ in. The selection of the proper pipe size is not a matter of empirical judgment, as might be supposed. On the contrary, the calculation of correct pipe size from hydraulic formulas is a more involved and complicated problem than in the case of water flow. The factors determining the rate of flow of oil through pipe lines are more numerous and more variable.

Before a calculation of rate of flow of oil through pipe can be attempted, it is necessary to know the viscosity of the oil at the temperature of flow, the friction factor for the pipe line under the conditions of flow, the working pressure and permissible pressure drop for creating the flow, and the other factors which customarily enter into any hydraulic formulas of this type, i.e., inside pipe dimension, length of pipe line, acceleration due to gravity, etc.

Two fundamental formulas to be used for viscous (oil) flow in pipes are given by Walker, Lewis and McAdams* of the Massachusetts Institute of Technology. The first of these provides a means of securing an expression for oil viscosity in absolute units, needed for use in mathematical processes, from the ordinary commercial expression for viscosity, usually given in seconds Saybolt. (By this is meant the time in seconds required for a given quantity of the fluid to pass through the fixed orifice of an instrument called a viscosimeter.) The relationship between the time of efflux (t), the viscosity (Z), and specific gravity (s) at the temperature of observation is given by the formula

$$\frac{Z}{s} = 0.220\ (t) - \frac{180}{t} \qquad (1)$$

The value of Z thus found is an absolute value referred to water as standard. It should be noted, however, that the formula itself is applicable only to fluids with Saybolt viscosities greater than 28.6 seconds, since the formula will give a negative result for values under that.

The second formula gives the relationship between pressure drop, length of pipe line, etc., as follows:

$$p = \frac{4fsLu^2}{2gd} \qquad (2)$$

where

p = pressure drop in pounds per *square foot*,
f = friction factor for the conditions of flow,
s = specific gravity of the liquid flowing, as pounds per cubic foot.
L = length of straight pipe in feet, plus equivalent length due to bends, etc.
u = average velocity of flow in feet per second.
g = acceleration due to gravity, about 32.2 ft. per sec. per sec.
d = inside diameter of pipe in *feet*.

For average fuel oils we can insert the value of 56.2 lb. for specific gravity; also substituting 32.2 for g, and dividing by 144 to give results in pounds per sq. in., which is more convenient for ordinary purposes, the formula resolves to

$$p = 0.024\frac{fLu^2}{d} \qquad (3)$$

Of the four remaining variables, f, L, u, and d, all but f are simple expressions. The value of f is determined by the conditions of flow, so that it becomes apparent that the solution of an oil flow problem involves "trial and error" methods; that is, certain relationships must be assumed at the start and then checked back through the formulas for conformance to theory.

A simple means of determining f is with the aid of the graph shown as Fig. 5, or with the equation

FIG. 4 — THE FORGE ROOM. *A*, BLOWER FOR FORGES; *B*, FORGES

* Walker, Lewis, and McAdams, "Principles of Chemical Engineering."

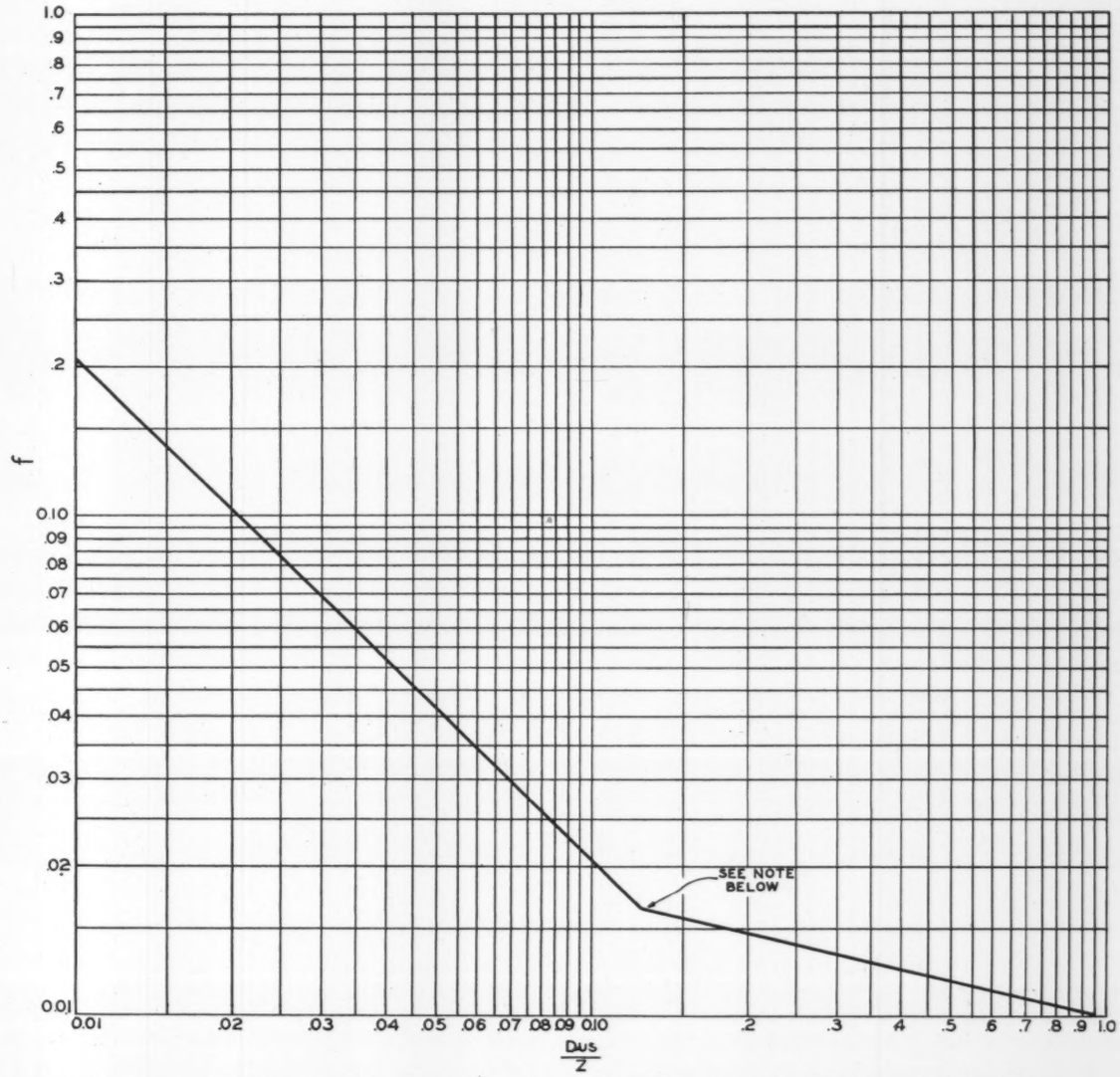


FIG. 5—SHOWING THE RELATION BETWEEN f AND Dus/Z. FOR VALUES OF Dus/Z GREATER THAN 0.126, THE FLOW BECOMES TURBULENT AND THE VALUES OF f CORRESPONDINGLY FALL ALONG A DIFFERENT CURVE. THIS CURVE IS CORRECT ONLY FOR CIRCULAR STEEL OR CAST IRON PIPE.

$$f = 0.00207 \frac{Z}{Dus} \qquad (4)$$

Both methods are really identical, the graph merely shows values of f corresponding to values of Z/Dus. The graph is plotted on logarithmic co-ordinates, and the reciprocal value Dus/Z is taken for abscissa, while the value of f is given as ordinate. In this process, Z is the absolute viscosity given in equation (1), D the inside diameter of pipe in *inches,* and u and s are velocity and specific gravity, respectively, as before.

Now to apply these equations to the problems of the plant under consideration. We know the quantity of oil to be pumped per hour, the length of suction line from tank to pumps, but we do not know what size pipe will be needed. Obviously a simple algebraic solution of equation (3) is not possible, for while we must keep the pressure drop below atmospheric pressure, which produces the flow, the value of f in (3) depends upon pipe diameter, as shown in (4), and it is pipe diameter which we are attempting to find. It becomes necessary, therefore, to assume a pipe size and work through the various formulas.

As an illustration, assume a 1-in. suction line between the tank and pumps. The actual inside diameter of a 1-in. pipe is given in the manufacturers' tables as 1.05 in. Other known data are specific gravity, 0.9; Saybolt viscosity, 200 seconds.

First the absolute viscosity is obtained with equation (1).

$$Z = s\left(0.22t - \frac{180}{t}\right) = 0.09\left(0.22 \times 200 - \frac{180}{200}\right) = 38.8$$

The velocity of flow, u, through a 1-in. pipe is evaluated as

$$u = \frac{500/7.5}{3600 \times \pi \times (1.05)^2/4 \times 1/144} = 3.4 \text{ feet per second.}$$

We then proceed to evaluate the modulus, Dus/Z as $1.05 \times 3.4 \times 0.9/38.8$, which equals 0.083. Corresponding to this, on Fig. 2, we find $f = 0.022$. Now equation

(3) gives us the pressure drop through the suction line, which has an equivalent length of about 100 feet.

$$p = \frac{0.024 \times fLu^2}{d} = \frac{0.024 \times 0.022 \times 100 \times (3.4)^2}{0.083}$$

$$= 7.35 \text{ lb. per sq. in.}$$

Since our atmospheric pressure is, of course, about 15 lb. per sq. in., it appears that with a 1-in. pipe line we will use almost half in overcoming friction and securing flow in a new, clean, steel pipe. It is almost certain that continued operation would not only corrode the pipe, increasing the value of f, the friction factor, but would also cause the deposition of sediment at points along the line, further restricting the flow. Hence a 1-in. suction line would be rather dangerous.

In a similar fashion, the values of the pressure drop for other sizes of pipe can be calculated. The values so found are listed in the following table:

Pipe Size	Actual Inside Diameter	Pressure Drop for 100 Feet
1 in.	1.05 in.	7.35 lb. per sq. in.
1¼ in.	1.38 in.	2.51 lb. per sq. in.
1½ in.	1.61 in.	1.27 lb. per sq. in.
2 in.	2.07 in.	.48 lb. per sq. in.

By increasing the size of pipe from 1 in. to 2 in., the pressure drop in the suction line was reduced from 7.35 to 0.48 lb. per square inch, a reduction of about 93 per cent. Considering all the variables that enter into oil flow, this extra investment was excellent insurance against plugged lines and inadequate flow.

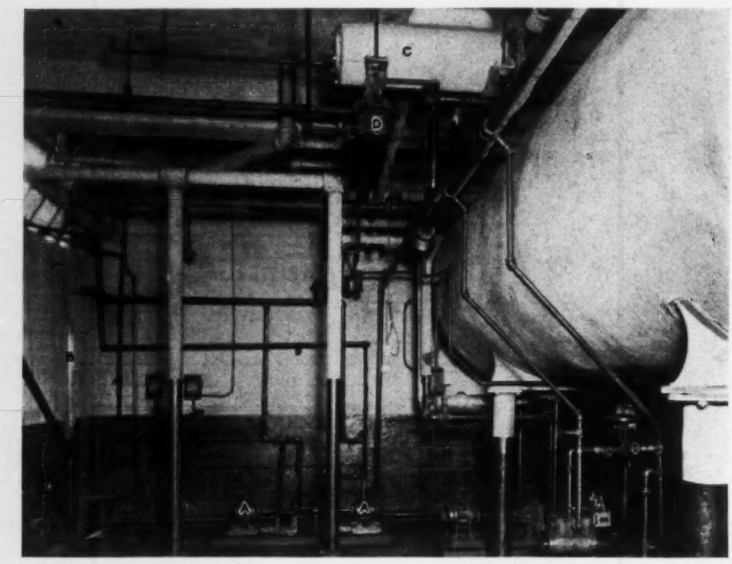


FIG. 6—THE OIL PUMPING SETS AND THE OIL PREHEATING SYSTEM. *A*, DUPLICATE OIL PUMPING SETS; *B*, GAGE SHOWING QUANTITY OF OIL IN UNDERGROUND TANK; *C*, OIL PREHEATING SYSTEM; *D*, TRAP

In the same manner the size of the pressure lines to the burners may be calculated. The principal changes of calculation would be the different values depending on the change of viscosity of the fuel oil after preheating. After passing through the heater and having its temperature raised to about 170 F, the viscosity would fall to about 100 seconds Saybolt.

Air Filters Aid Hay-Fever Cases

CONCERNING the use of air filters for hay-fever work, the use of such equipment in hospitals has, of course, become quite general. Most of the larger recent hospitals are well provided with air cleaning equipment. It is only lately, however, that attention has been given to the use of air filters in the control of respiratory diseases.

The writer has given considerable attention to this subject in the last few years and recently visited institutions in various parts of the country to discover what is being done in this field. I find the management of one of the largest hospitals on the Pacific coast was of the opinion that hay-fever and asthma complications in its tuberculosis and post operative wards were a considerable factor in increased mortality at certain seasons of the year. The doctor in charge of one of these hospitals in Chicago, who had arranged an especially constructed room with filtered air for the treatment of hay-fever and asthma, was also of the opinion that hay-fever, asthma and similar disorders could often be benefitted by the removal of irritating impurities and pollens from the atmosphere.

There have been recent important contributions to our knowledge of this phase of air conditioning. It is now apparent that we can use air cleaning equipment in the prevention and control of these disorders with a high percentage of success. It is increasingly apparent that many diseases, the causes of which were obscure and little understood, are influenced by air-borne impurities. It may be pollen of trees, grasses, flowers; it may be substances of such common occurrence as starch dust, face powders, cat and dog dandruff, etc. We are learning to view with suspicion the "cold" which hangs on, either in summer or winter. In many cases it has been found that a certain specific pollen or impurity in the air is the cause of these disorders.

Sufferers from hay-fever, bronchial asthma, migraine, etc., have discovered in many cases they can obtain relief from their symptoms in certain of the department stores, theaters and places of public assemblage which are equipped with modern systems of air conditioning. During the hay-fever season they have, indeed, been somewhat of a problem to the management of certain of the department stores. They have arrived early and enjoyed the facilities of these man-made hay-fever resorts to the utmost so much so that sometimes the management was forced to remove benches and chairs from the air conditioned floors.—*H. C. Murphy.*

Indicating Instruments aid Operation of Heating and Air Conditioning System

By S. A. McGuire*

The heating and air conditioning system in the American Academy of Arts and Letters Building is adequately equipped with indicating gages and thermometers to assist in its proper operation. The designing engineer will find several valuable pointers in the description of this recently dedicated structure.

THE AMERICAN ACADEMY of Arts and Letters Building, dedicated a few weeks ago, is located at 632 West 155th street, New York City, and was designed by Cass Gilbert, Inc. It is a part of the Huntington group, among the other buildings of which are American Numismatic Society, Museum of the American Indian, Hispanic Society of America, American Geographical Society, and others. It faces north, has a 100-ft. frontage, is about 116 feet deep, and is designed in the Italian renaissance style, with the front of face brick and limestone. The building contains a basement, main floor, balcony and loge floor, and an exhibition room above.

The basement has locker and check rooms, toilet rooms, a plenum chamber, tuning rooms, and the heating and air conditioning equipment. On the ground floor are the lobby, the auditorium, 70 by 65 feet and 34 feet high, having a sloping floor, and corridors on the east and west sides. The auditorium seats 534. The stage is of ample size and has modified theatrical equipment with tri-colored disappearing footlights, border lights, and stage pockets,—all of which, together with the auditorium lighting, are controlled by dimmer banks.

In the rear of the stage are the reception and green rooms. The balcony is at the rear of the auditorium and directly over the entrance lobby; it has a seating capacity of 168. Loges are located on either side of the building, between arches, which are a main feature of the interior design. Above the northerly end of the balcony and auditorium is the exhibition room, about 45 by 70 feet, and 28 feet high. It is lighted naturally by an outer skylight and an inner ceiling light 32 by 56 feet. It is electrically lighted by 112 reflectors, giving approximately 30 foot-candles on the walls. This exhibition room is reached either by a raised terrace running from Broadway to the Academy, or through

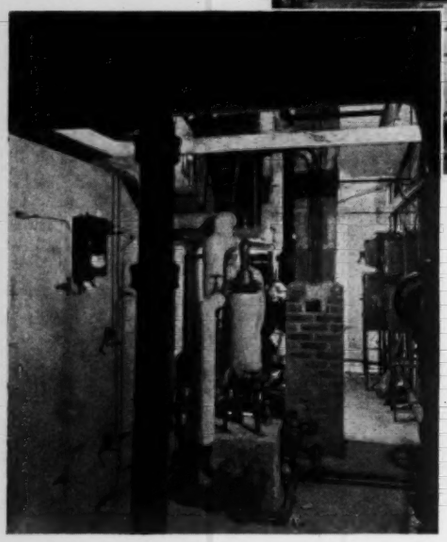
ABOVE — SOUTH ELEVATION, FROM THE TERRACE OF THE AMERICAN ACADEMY OF ARTS AND LETTERS

BELOW—THE FRONT ELEVATION

* Cass Gilbert, Inc., New York City.

RIGHT — PART OF THE BOILER ROOM

BELOW — EXHIBITION ROOM SUPPLY, SHOWING THE HUMIDITY CONTROL, FILTER GAGE, ETC.



the older building, which is directly south.

Forced Draft Control

The Academy is entirely of fireproof construction. The heating plant consists of two 79-inch, 15-section cast iron boilers. These are equipped with a forced draft blower and arranged for burning No. 1 buckwheat coal, with full automatic control. In addition to the usual damper regulators, the boilers are equipped with a control for the purpose of closing off the forced draft blower when the pressure in the boilers reaches a predetermined amount. In this installation, the pressure control is set at about 1 lb., the circuit being opened when that pressure is reached. A forced draft system was installed for firing-up purposes only.

The vacuum heating system maintains a vacuum of 10 inches of mercury. The piping system consists of the standard two-pipe arrangement, with separate lines from the boilers to and from the air heaters. Each section and circuit is valved. The piping was welded where practical, screwed fittings being used where welding difficulties were encountered; the couplings were generally welded in after being screwed. The piping system was designed for a pressure drop of one oz. per 100 ft.

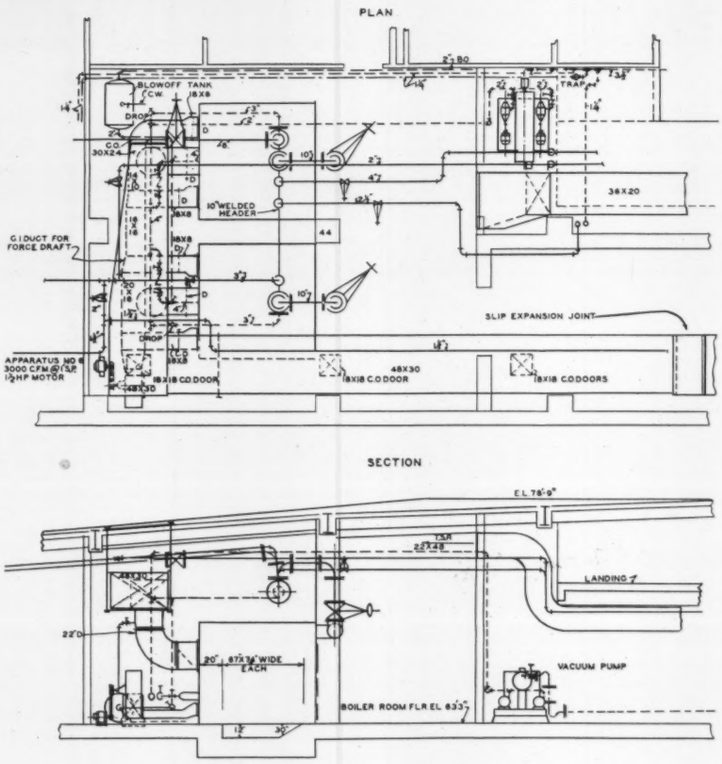
The piping was tested with air at 20 pounds per square inch.

The heat losses of the building (about 615,000 Btu's) are absorbed by approximately 2,000 square feet of direct radiation, excepting those of the exhibition room, wherein the heat losses are taken care of, and the room ventilated by, a blower unit.

The Air Conditioning System

The ventilating system is divided into five units. Two of the units are provided with air-washers, the one for the main auditorium with a double spray bank, and that for the exhibition room with a single bank. Fresh outside air is provided for the ventilation, no air being re-circulated, although for hurriedly warming the building with a minimum of steam, re-circulated air may be used.

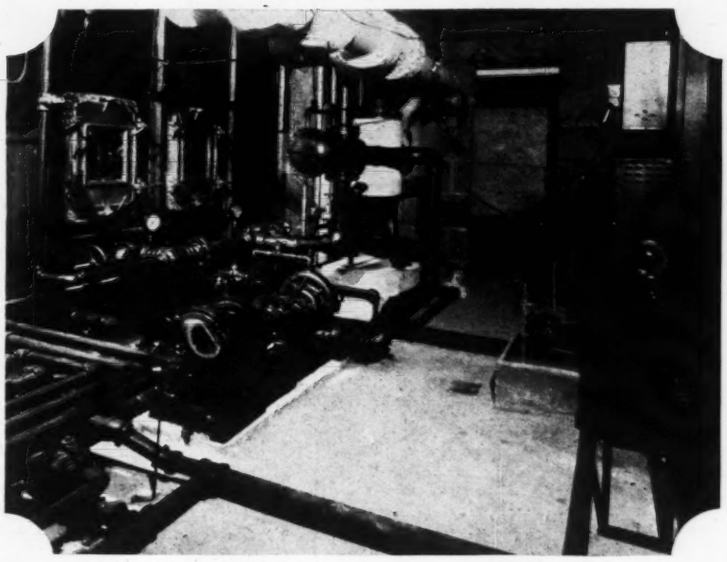
Air is taken into the building at the highest point, the intake being located at the northwest corner of the building about 72 ft. high and well to windward of the stack, the prevailing winds being northwest. The air is carried to a cold air chamber in the basement through a masonry shaft, is then passed through filters, thence to the pre-heaters, through the air-washers, then re-heated to the desired temperature, from which it is drawn into the blower housing, and thence discharged through the ducts.



DETAIL OF BOILER AND PUMP ROOMS

The main supply unit for the auditorium, balcony, loges, and reception rooms consists of a double-width blower, the washer and the heaters, all located in the northwest section of the basement.

The system for this portion is of the down-feed type; that is, the fresh air supply is delivered through grilles in the ceiling, and the vitiated air is exhausted through mushroom ventilators under the seats in the auditorium and through step-grilles in the balcony. The mushroom ventilators in the auditorium floor connect directly with the plenum chamber in the



THE AIR WASHERS FOR THE AUDITORIUM AND GALLERY SUPPLY

basement, from which the exhaust air is drawn through a single width blower and discharged at the roof close to the stack and about 80 feet away from the fresh air intake.

Owing to the design and construction of the building, it was impossible to reach the ceiling outlets with supply ducts in any other manner than by running the main trunk line horizontally to practically the full length of the building, then vertically to a point just below the terrace level, thence horizontally to the front of the building, the necessary branches being taken off as the duct system was extended. This required a large amount of sheet metal work—approximately 110,000 pounds.

Discharge Velocities

The discharge velocities were calculated at about 400 feet per minute, but, owing to an architectural redesign of the ceiling grilles, the free area was increased with a corresponding velocity drop. The variation in velocities may be noted on the sheet setting forth the actual test; during which test a number of smoke-pots were used to ascertain both the movement of the air and how close to the breathing line it would penetrate. By actual test, the smoke fumes averaged a penetration of approximately 8 feet above the floor. This, however, was tested under conditions which were not altogether conducive to best results, many doors being open which obstructed and interfered with the movement of the air. A further test will be made when the building is ready for occupancy, at which time the conditions will be better. The air will undoubtedly reach its proper point at a comparatively low velocity, and be removed through the exhaust registers, in a time proportionate to the air delivery, and without drafts.

The adjustments will necessarily be of a minor character, as the ventilation seems to be at least 90 per cent ideal. Its design was based upon occupancy rather than a number of air changes per hour. The amount of air delivered is 50 cubic feet per person, maximum, and graduates down to about 25, depending upon the speed of the blower,—or equal to approximately 12 changes per hour maximum.

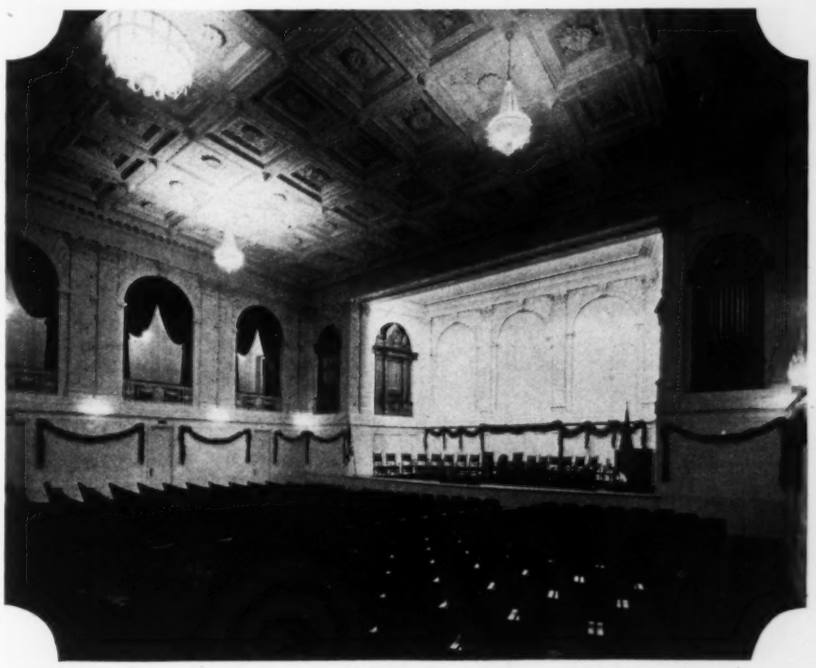
Each supply unit is provided with filters designed for a velocity of approximately 300 feet per minute. These are placed in the cold air chamber just ahead of the pre-heaters. Every precaution has been taken to supply fresh and clean air for the occupants.

Velocities in the Ducts

The air velocities through the system are comparatively low, those in the duct system averaging about 1100 feet a minute, the supply air through the registers from about 200 to 300 feet, the exhaust air through the registers from about 150 to 200 feet. The supply air registers are generally located (except in the auditorium, balcony and loges) on the walls, from about 8 to 15 feet above the floor, depending upon the story height. The exhaust registers occur generally at the height of the base board.

Control of Wet and Dry Bulb Temperatures

The air supply units are provided with fin-type radiation, a single row for preheaters and a double



THE AUDITORIUM

row for reheaters. The preheaters are under hand control; the reheaters, under thermostatic control; the temperature of the air leaving each fan is held constant by means of a two-point thermostat in the fan discharge, controlling steam valves at the reheaters. This control has been arranged for the auditorium and balcony unit, where it is necessary to bring in the air at a temperature slightly below that desired in the rooms, in order to absorb and carry off the heat generated by the assembled audience.

Main Supply, Showing Typical Belt-Guard

In each apparatus, the wet bulb temperature at the point of saturation, that is, where the air leaves the washer, is held constant by means of an intermediate thermostat, controlling a hot and cold mixing valve of the reverse acting type on the spray water supply line. By maintaining a fixed wet bulb temperature at this point, a constant predetermined relative humidity is obtained in the supply air after it has passed the reheaters. It is expected that dry bulb temperatures of 68 to 70 degrees in the building, with a relative humidity of 50-55 per cent will generally be maintained.

Controlling Temperature in Room with Skylight

The arrangement installed for controlling the air supplied to the exhibition room incorporates a slight modification from that used in the main unit, which provides ventilaton for the auditorium and balcony. In the exhibition room is placed a pilot thermostat, coupled with the main thermostat, near the discharge grilles, designed to change the temperature of the incoming air to conform with the fluctuating demand for heat in the room, over which, as has been stated, is a very large skylight. Without the pilot the heat effect from the skylight would undoubtedly interfere very extensively with the desired temperature of the room.

The inlets to both supply fans, and the outlets from both main exhaust fans, are equipped with automatic louvre dampers, operated pneumatically and controlled from a central point in the basement.

Thermometers and Gages

The entire temperature control system in connection with the air conditioning system is operated by a duplex set of electrically driven air-compressors. The main supply units are provided with hygrodeiks set in the main air-passage and about six feet from the fan discharge. These are equipped with wet bulb and dry bulb thermometers, and a psychrometric chart as an integral part of the instrument for readily ascertaining the relative humidity of the air as it is discharged through the system is posted nearby.

The direct radiation is thermostatically controlled by a self-contained automatic unit which regulates

Detail Showing Basement Units — North End

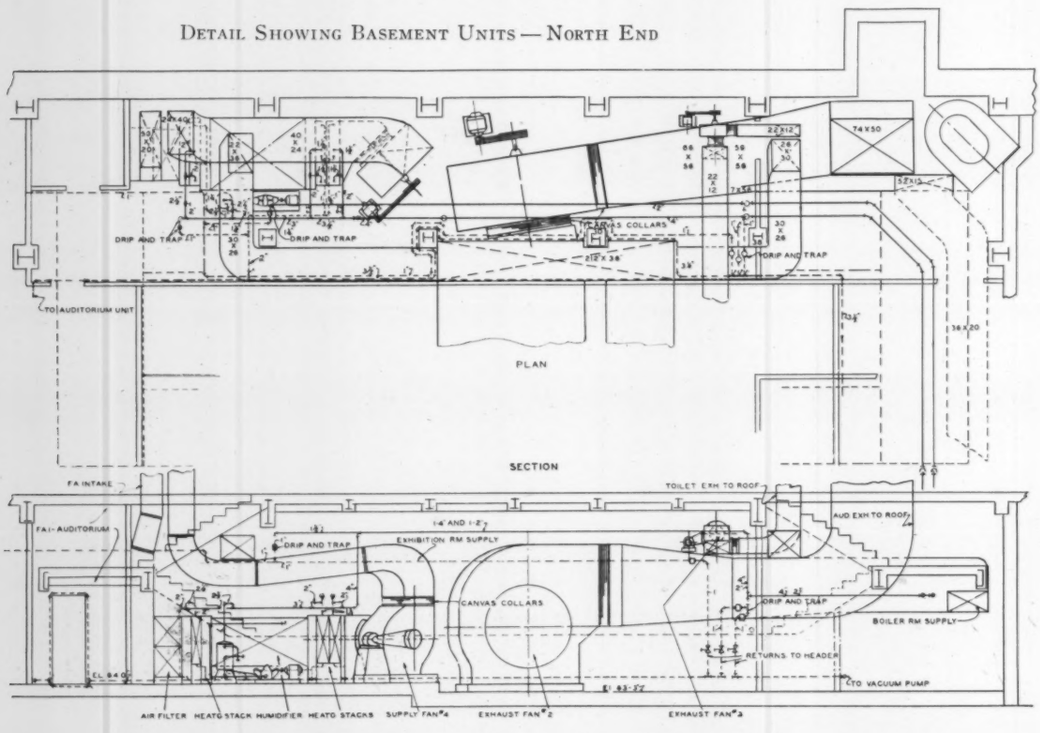


TABLE 1—RECORD OF VENTILATION TEST—AMERICAN ACADEMY OF ARTS AND LETTERS.
Test Run, June 30th, 1930.

APPARATUS	C.F.M.	FAN SPEED RANGE	MOTOR SPEED RANGE	OUTLET VELOCITY	DISCHARGE AREA SQ. FT.	NO. TRAVERSE	AVERAGE VELOCITY PRESSURE IN.	STATIC PRESSURE INLET IN.	STATIC PRESSURE DISCH. IN.	VEL. PRESSURE INLET IN.	TOTAL STATIC PRESSURE IN.	AMPERES	VOLTS	AIR WASHERS R.P.M.	AIR WASHERS LB. PRES.	AIR FILTERS RESISTANCE IN.
1	41340	285/160	850/420	1060	39	18	.07	.11	1.22	.05	1.28	85/54	208/210	1170	21	.3
2	31651	178/108	830/470	1021	31	18	.065	.22	.36	.03	.55	33/22	do			
3	1274	890	1140	910	1.4	6	.05	.3	.39	.05	.64	16/10	do			
4	7900	485/355	1100/800	1000	7.9	8	.05	.3	.9	.04	1.16	25/15	do	1790	20	.12
5	5400	440/270	1100/580	1200	4.5	12	.09	.15	.3	.03	.42		do			
6	4700	1700/850	1100/560	1680	2.8	4	.18	.10	.53	.02	.61	10/6	do			
					HP.	*Specification Requirements.*										
1	40400	312 Max.	840/420	1400	20						1.38					
2	28150	175 do	870/435	1400	7½						.63					
3	1350	880 do	1140	1400	¾						.63					
4	7000	522 do	1160/580	1400	5						1.38					
5	4000	437 do	1130/560	1400	1						.5					
6	3000	778 do	1170/580	1400	1½						1					

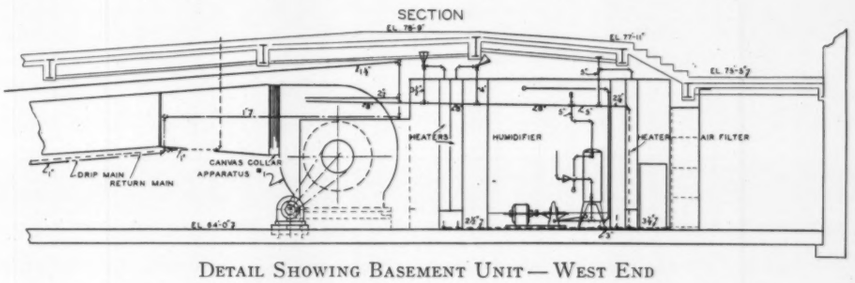
the air temperature at the radiator as exterior temperature changes occur.

The filters are equipped with resistance gages, pressures indicated in inches of water. The bottom of the plenum chamber was constructed with plaster boards in preference to the usual wire lath and plaster. This was done to minimize the air resistance, the plaster boards offering a much smoother surface than the plaster clinches.

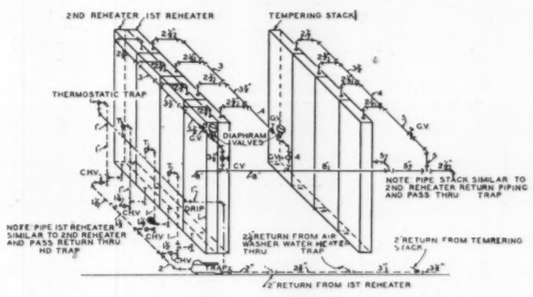
The motors of the fans are equipped with controlling devices, each with an average of about five steps, which give a speed range from 50 per cent to the maximum. The control panels are equipped with circuit breakers for motor protection.

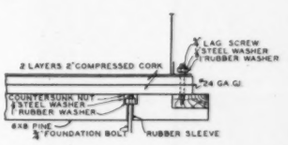
The system was tested, as is the writer's practice on all systems of this character. The test was run on June 30 last, just prior to the building's completion. The results are indicated on the various sheets accompanying this description. All tests of air deliveries at the fan outlets were made with pitot tubes, many traverses being made in the ducts in order to obtain correct velocity pressures.

The heating contractor was Thompson-Starrett Company, Inc., who also erected the building and installed the electrical and mechanical equipment (exclusive of the plumbing).



DETAIL SHOWING BASEMENT UNIT — WEST END


2ND REHEATER
1ST REHEATER
TEMPERING STACK
THERMOSTATIC TRAP
DIAPHRAM VALVES
NOTE PIPE STACK SIMILAR TO 2ND REHEATER RETURN PIPING AND PASS THRU TRAP
NOTE PIPE 1ST REHEATER SIMILAR TO 2ND REHEATER AND PASS RETURN THRU HD TRAP
2" RETURN FROM AIR WASHER WATER HEATER THRU TRAP
2" RETURN FROM TEMPERING STACK
2" RETURN FROM 1ST REHEATER



LEFT—DETAIL OF HEAT SURFACE PIPING. ABOVE—FAN AND MOTOR FOUNDATIONS

Simplified Practice for Wrought Pipe and Fittings

The division of simplified practice of the Bureau of Standards recently announced that simplified practice recommendation No. 57 for wrought iron and wrought steel pipe, valves, and fittings has been reaffirmed by the standing committee of the industry, without change, for another year.

98% Degree of Adherence

Reports from twelve manufacturers, in reply to a survey of their 1929 production of this product, conducted prior to the revision meeting, indicated their degree of adherence to the recommendation to be approximately 98 per cent.

Higher Pressures and Temperatures as They Affect the Design, Installation and Maintenance of Piping

Article No. 2

By J. J. Harman*

This is the second of Mr. Harman's three-part article; the first installment was published last month. It is the author's intention in this series to show what the past decade's trend toward higher pressures and temperatures means to the piping engineer. Some new material on the forces required to operate valves appears in this installment.

INCREASED WORKING pressures have a decided effect upon the power required to operate valves. Globe valves are usually mounted with the pressure under the disc.

Fig. 8 shows a high pressure globe valve in which the lower part of the disc is shaped to provide a venturi-type approach to the restricted throat at the seat when the valve is set in a throttling position; this special shape of the disc also aids materially in guiding the flow lines when the valve is wide open. The pointed end of the disc projecting through the valve seat is constantly scoured by the high velocity stream which aids in preventing the accumulation of carbon deposits when the valve is used on hot oil or hot oil vapor lines.

High pressure globe valves, however, become increasingly difficult to operate as the size of the valve increases and various devices have been used to overcome this difficulty. Fig. 11 shows one method of accomplishing this purpose. This valve is mounted with the pressure on top of the disc and is provided with a piston fitting loosely in a sleeve mounted in the body neck. A small by-pass valve is also provided for relieving the pressure above the piston and balancing the pressure on the disc so that the main valve may be easily opened or closed. When both the main valve and the by-pass valve are closed, the full working pressure of the line acts on the top of the disc and holds it tightly closed against leakage.

Gate valves are used extensively because of their straight line flow design, and the power required to operate them has become more important since working pressures have risen to higher and higher levels. Some users prefer the double disc type of gate valve and others prefer the solid wedge type. Both types have been used successfully on high pressures, but for extremely high pressures the wedge type is often preferred because of its rugged construction.

There is no recognized standard formula for the power required to operate gate valves, but the formulas shown in Figs. 9 and 10 for the force required at the rim of the hand-wheel to close and open both double disc and solid wedge O. S. & Y. gate valves have been checked against a number of actual operating tests on valves of various sizes operating at high and low pressures, and the results check within approximately plus or minus 25 per cent. Some disagreement is to be expected, of course, both in the friction coefficients and in the frictional resistance of the stem packing, and in addition to these variations, the force required to open the valve is affected to a considerable extent by differences in the force applied in seating the valve. So it is not contemplated that the force required to operate valves under all conditions can be computed with exact precision. It is felt, however, that the formulas are sufficiently accurate for general estimating purposes.

Factors Affecting Gate Valve Operation

The elements of friction entering into the operating of a gate valve are as follows:

1. Sliding friction of valve seats
2. Stuffing box friction
3. Stem thread friction
4. Yoke nut friction
5. Friction of gearing and bearings, if back gears are used

The mechanical efficiencies used in the formulas are based on the following:

1. Coefficient of friction of unlubricated valve seats	=	.200
2. Stuffing box efficiency	=	85 per cent
3. Coefficient of friction stem thread	=	.143
4. (A) Ball bearing yoke efficiency	=	100 per cent
(B) Plain yoke efficiency	=	50 per cent
5. (A) Spur gearing efficiency	=	90 per cent
(B) Bevel gearing efficiency	=	85 per cent

Unbalanced Pressure on Bottom of Valve Stem

An additional factor entering into the stem thrust in opening and closing a valve is the unbalanced pressure acting on the bottom of the valve stem. This factor is provided for in the formulas, and while it is often overlooked or neglected in computations of this character, it is nevertheless of considerable importance at high pressures, particularly in the smaller sizes of valves. The effect of this unbalanced pressure in fact is quite noticeable in operating high pressure valves, the torsional

* Research engineer, Walworth Company, Boston, Mass.

effort required to operate the valve when the stem is being forced into the valve body being considerably greater than that required when the stem is being withdrawn.

Fig. 12 shows how the torsional effort required to close plain yoke wedge gate valves increases as the working pressure and size of valve increase. Various devices are used to compensate for this large increase in the force required to operate the valve, such as small by-pass valves to equalize the pressure on both sides of the main valve, ball bearing yokes (see Fig. 13), special hand-wheels providing a ready means of applying additional leverage when needed (see Fig. 14), and if these do not suffice back gearing of either the spur or bevel gear type may be provided (see Figs. 15 and 16). Fig. 17 shows a rather special type of back gearing used on a 24-in. by 16-in. venturi-type valve for 800 lb. gas working pressure in which two tiller-type hand-wheels were used, one on the slow speed gear ratio for seating and unseating the valve, and the other on the high speed gear ratio for more rapidly opening and closing the valve. Fig. 18 shows an installation of lubricated plug cocks on a high pressure gas line which are also used in this class of service.

Back gearing, of course, increases the time required to open and close the valve, and at important control points in the piping systems it is becoming more and more common to provide power units for operating the valves, and a remote control station strategically located for operating the entire group of valves. A common method of applying power to a valve is to use an electric motor control, as in Fig. 19; valves are often operated by air or hydraulic cylinders, as in Fig. 20.

Increased Cost of High Pressure Piping

It would seem at first thought that the heavy construction required for safely handling high pressures would enormously increase the cost of high pressure piping, valves and fittings. However, the fact that the high pressure system contains a much greater quantity of available energy per unit of volume greatly reduces the size of piping required. In steam power plants, even with the added piping required for the re-heat cycle, the increased cost of 1,400-lb. pressure piping above the 300- and 400-lb. pressure systems has been found to range from 17 per cent to 25 per cent, and with the accumulation of more experience in the high pressure technique, it is logical to expect that this difference in cost eventually will be reduced if not entirely wiped out.

Figs. 21 and 22 show in graphic form the reduction in volume of fluid to be handled as the pressures are increased for both hydraulic and steam systems, and the smaller sizes of piping required compensate in large measure for the added cost due to the heavy construction.

Effect of High Temperature on Design

Higher temperatures require construction metals that retain their strength and hardness to a marked degree and do not undergo physical changes of structure which materially lower the load-carrying ability of the metal when it is intermittently or continuously subjected to elevated working temperatures.

While all metals fall off in strength and hardness at elevated temperatures, some metals retain these desirable physical properties very much better than others. It has been found by laboratory tests and by successful utilization in industry, that one of these, steel, retains its physical properties very well at the temperatures now in common use and that it is not subject to serious deterioration either by long exposure to these temperatures or by repeated cycles of heating and cooling.

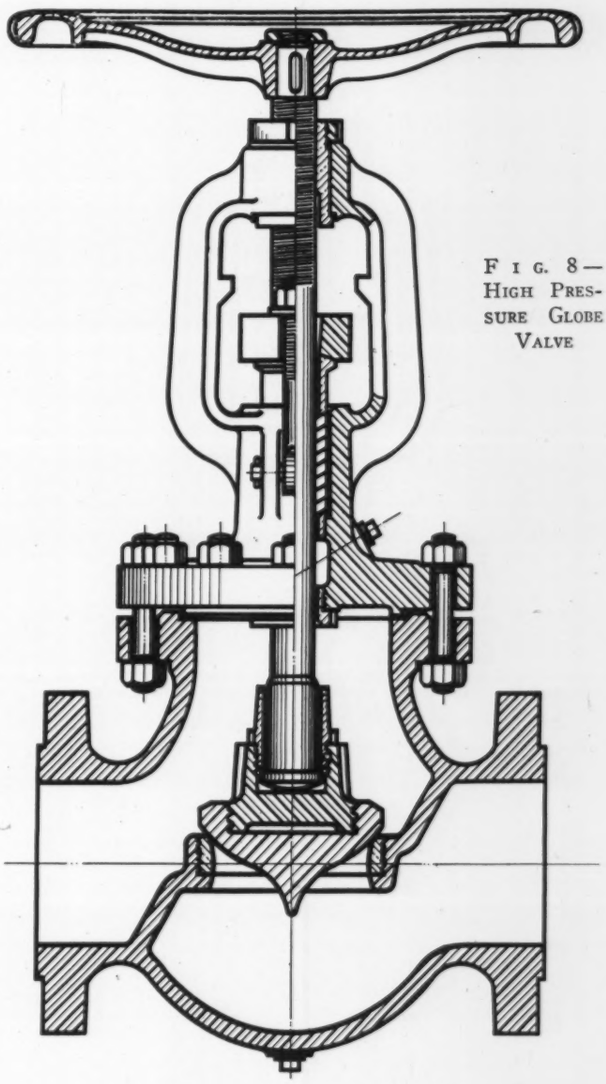
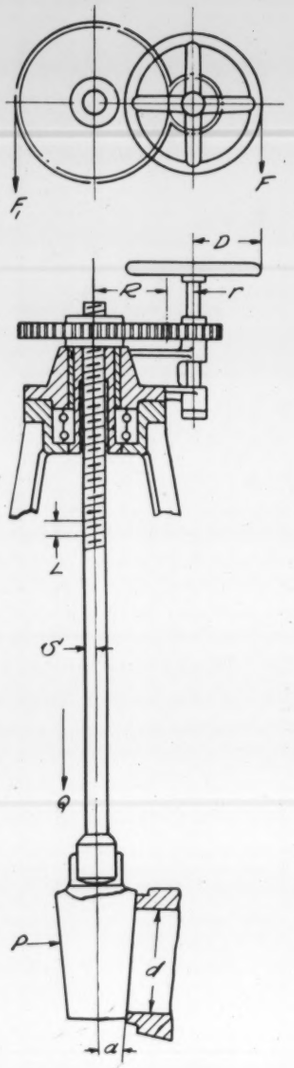


FIG. 8—HIGH PRESSURE GLOBE VALVE

The upper limit of working temperature for cast iron when used for fluids other than steam is, in most instances, being held down to 450 F. Malleable iron fittings are also usually limited to 450 F maximum temperature, although in the oil industry they are being successfully used at much higher temperatures. High grade bronze valves are usually used for temperatures up to 500 F and for temperatures above this steel valves and fittings are generally employed.

Range of Temperatures

Tentative American Standard B-16E for steel pipe flanges and flanged fittings does not establish working temperature ratings above 750 F, and until quite recently this has been considered the upper limit for steam temperature in this country. In Europe, however, work-



Q = Stem Thrust
F = Force at Handwheel Rim - geared
F_1 = Force at Handwheel Rim - without gears
D = Radius of Handwheel
R = Pitch Radius of Gear
r = Pitch Radius of Pinion
L = Lead of Stem thread
d = Port Dia
P = Working pressure lbs. per sq. in.
S = Pitch Radius of stem thread = $\frac{2d_s - (p+.02)}{4}$
p = Pitch of Stem thread
d_s = Stem diameter
δ = Angle of Stem thread

$\tan\delta = \frac{L}{6.28\,S}$

$\frac{\mu}{\phi}$ = Coefficient of Friction	μ Valve Seat Dry	ϕ Stem Thd. Oiled
Brass to Brass	.20 = 11.5°	.143 = 8.2°
Steel to Steel	.20 = 11.5°	.143 = 8.2°
Steel to Brass	.20 = 11.5°	.143 = 8.2°

β = Mechanical Efficiency of Valve operating mechanism exclusive of stem thread friction

	Pl. Yoke	B.B. Yoke
without gearing	42%	85%
with spur gears	38%	76%
with bevel gears	36%	72%

α = Angle of Wedge = 5°

Force to close valve

$Q = .7854\,P[d^2\tan(\mu+\alpha)+d_s^2]$

$F_1 = \frac{Q}{\beta}\tan(\phi+\delta)\frac{S}{D}$

$F = \frac{Q}{\beta}\tan(\phi+\delta)\frac{S}{D}\times\frac{r}{R}$

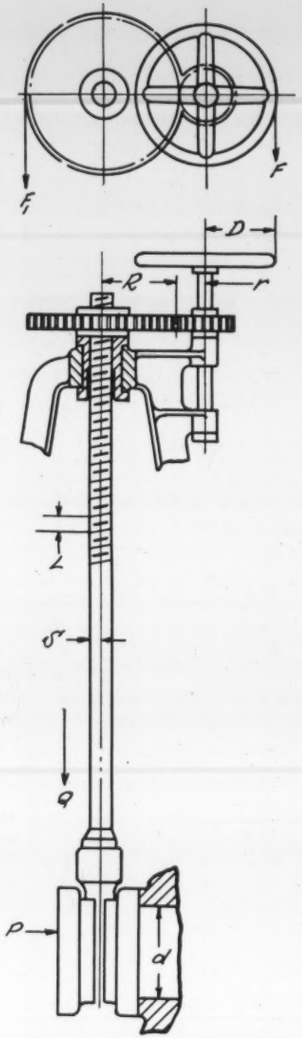
Force to open valve

$Q = .7854\,P[d^2\tan(\mu+\alpha)-d_s^2]$

$F_1 = \frac{Q}{\beta}\tan(\phi+\delta)\frac{S}{D}$

$F = \frac{Q}{\beta}\tan(\phi+\delta)\frac{S}{D}\times\frac{r}{R}$

FIG. 9—FORCE AT RIM OF HAND-WHEEL REQUIRED TO OPERATE O. S. & Y. WEDGE GATE VALVE



Q = Stem Thrust
F = Force of Handwheel Rim - geared
F_1 = Force at Handwheel Rim - without gears
D = Radius of Handwheel
R = Pitch Radius of Gear
r = Pitch Radius of Pinion
L = Lead of Stem Thread
d = Port Diameter
P = Working pressure lbs. per sq. in.
S = Pitch Radius of stem thread = $\frac{2d_s - (p+.02)}{4}$
p = Pitch of Stem thread
d_s = Stem diameter
δ = Angle of stem thread

$\tan\delta = \frac{L}{6.28\,S}$

$\frac{\mu}{\phi}$ = Coefficient of Friction	μ Valve Seat Dry	ϕ Stem Thread Oiled
Brass to Brass	.20 = 11.5°	.143 = 8.2°
Steel to Steel	.20 = 11.5°	.143 = 8.2°
Steel to Brass	.20 = 11.5°	.143 = 8.2°

β = Mechanical Efficiency of Valve operating mechanism exclusive of stem thread friction

	Pl. Yoke	B.B. Yoke
without gearing	42%	85%
with spur gears	38%	76%
with bevel gears	36%	72%

Force to close valve

$Q = .7854\,P(d^2\tan\mu + d_s^2)$

$F_1 = \frac{Q}{\beta}\tan(\phi+\delta)\frac{S}{D}$

$F = \frac{Q}{\beta}\tan(\phi+\delta)\frac{S}{D}\times\frac{r}{R}$

Force to open valve

$Q = .7854\,P(d^2\tan\mu - d_s^2)$

$F_1 = \frac{Q}{\beta}\tan(\phi+\delta)\frac{S}{D}$

$F = \frac{Q}{\beta}\tan(\phi+\delta)\frac{S}{D}\times\frac{r}{R}$

FIG. 10—FORCE AT RIM OF HAND-WHEEL REQUIRED TO OPERATE O. S. & Y. D. D. GATE VALVE

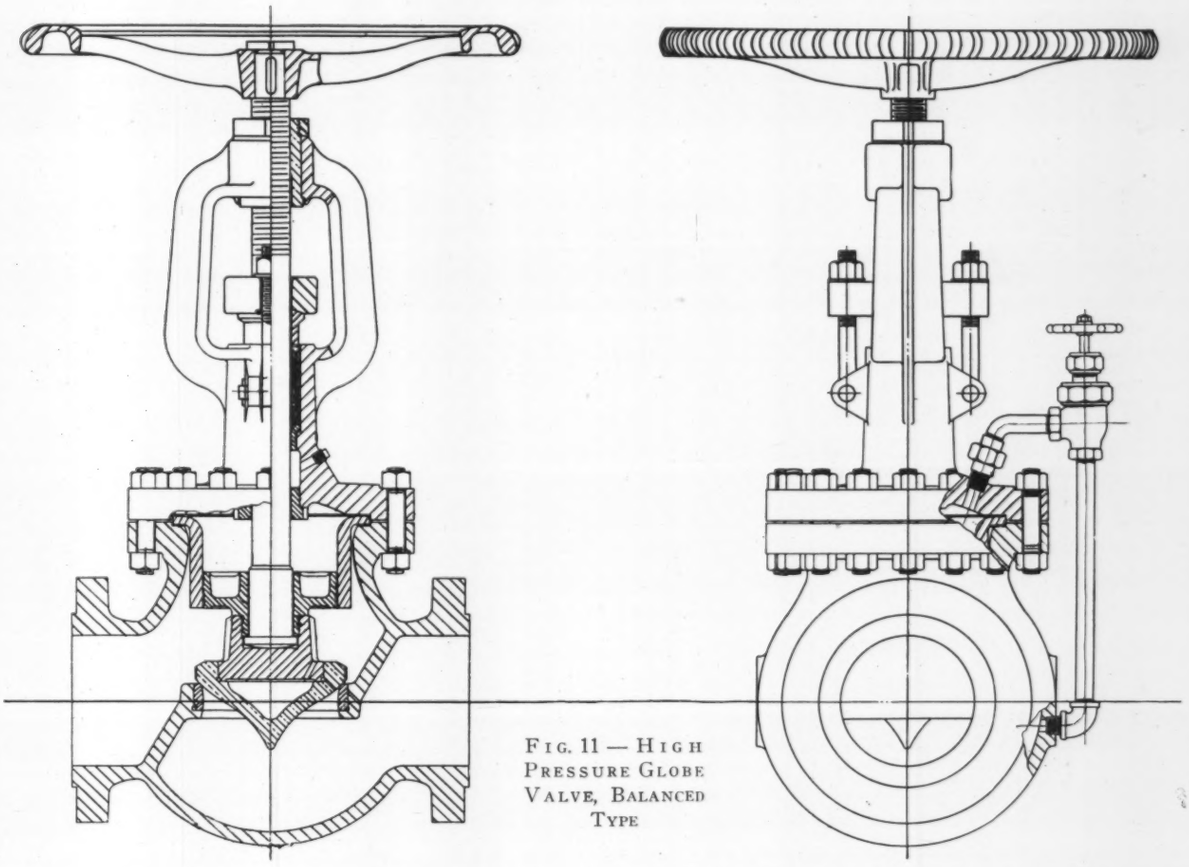


FIG. 11 — HIGH PRESSURE GLOBE VALVE, BALANCED TYPE

ing steam temperatures in the neighborhood of 900 F have been used successfully with the conventional types of construction metals, and the desirable gain in economy to be secured by the use of higher working temperatures is tending to break down the 750-deg. barrier and lead the power engineers into a higher temperature zone. One steam power plant is being constructed at the present time in this country which will operate at 1,800 pounds pressure and 850 F temperature, and an experimental central station unit of 10,000 kw capacity is being installed which will operate at 1,000 F.

As previously mentioned, the oil industry has been using high working pressures very extensively for the past several years at operating temperatures of 900 F and higher, and plain carbon steel has been found satisfactory in this service from the standpoint of heat resistance, although *in some cases* it has not been satisfactory from the standpoint of corrosion resistance. The severe requirements of *high pressure-high temperature* service, however, and the constant upward trend of pressures and temperatures have stimulated a great deal of laboratory research in an effort to determine accurately the strength and general performance characteristics of our usual metals when subjected to high temperature under stress for long periods of time, and also in an effort to develop new alloys which will show better physical properties without appreciably increasing the cost of the product.

Creep Tests

The results of these investigations indicate that the conventional short time tests conducted at elevated temperatures do not give the whole story in regard to the long time performance of metals, particularly at temperatures above 750 F, because at the higher temperatures the unit stresses at which the metals begin to show objectionable plastic properties are lowered to a considerable extent. If the unit stress is too high, the metal *flows* or *creeps* slowly, but continuously, and when the cross-sectional area becomes less, due to the flow of metal, the rate of creep becomes increasingly rapid and the metal finally fails. Laboratory creep tests extending over periods ranging from 500 hours to six months have been made by a great many investigators, but unfortunately in view of the fact that the apparatus and testing technique for tests of this character have not as yet been fully developed and standardized, the published results of different investigators have indicated widely different creep values for the same metals. In fact, the interpretations of test results in predicting the long time performance of the metals in service in some cases have been directly contradictory to the actual performance records of the same metals in numerous industrial installations which have been in operation for much longer periods of time than those covered by the laboratory tests.

These discrepancies between various laboratory tests and actual service tests can no doubt be explained by errors in observation of the extremely small measurements which must be taken in making creep tests, due possibly to improper design of the test apparatus, friction in the mechanism employed—which makes the actual stress in the test specimen uncertain—and misinterpretation of deviations in apparent length of the test specimen caused by variations in temperature of the test specimen and of the test apparatus.

The friction of the mechanism increases the actual stress in the specimen above the observed value when it attempts to raise the weights. Heat radiated from the furnace used for testing the specimen, and small increases in room temperature acting over the entire length of the testing machine frame, tend to elongate the testing machine and add to the actual stress in the specimen. Some investigators also neglect the reduction in effective cross-sectional area of the small test specimen caused by oxidation at the high temperatures during the long test period. While all these errors may be small within themselves, they are cumulative, and all tend toward imposing a higher actual stress on the specimen than the observed value.

Creep tests, of course, are adding materially to our store of knowledge regarding the behavior of metals under stress at high temperatures and eventually the interpretation of test results of this character undoubtedly will be brought into close agreement with actual service records, but, in the meantime, there is no occasion for undue alarm when laboratory tests appear to indicate a condition that actual service tests of long duration do not show.

Safe Stress Curve for .30 Carbon Cast Steel

Fig. 23 shows the ultimate tensile strength and yield point values of a good grade of .30 carbon cast steel in the thoroughly annealed condition as determined by short time high temperature tests, together with long time creep tests values in the zone above 750 F, and a safe stress curve. In the temperature zone up to and including 750 F, this safe stress curve has been quite definitely established, and in the zone from 750 to 1,000 F, performance records of valves and fittings in actual service for long periods have not shown any objectionable creep which interfered with their performance in service. The higher value shown for the safe stress at 150 F is used for non-shock working pressure ratings for oil, water, gas and similar fluids, and a larger factor of safety and lower safe stresses are used in the higher temperature zone where the flashing of a liquid into vapor may cause sudden rises of pressure.

The exact nature of the *flow* of steel in the vicinity of 1,000 F and above is not definitely known as yet, one school of investigators believing that the flow follows the general laws of a plastic solid, and another school believing that it more nearly resembles the flow of a viscous fluid. If the first theory be true there is, of course, a limiting creep stress below which no flow occurs, and if the second be true, flow occurs in time at all stresses no matter how small.

Equicohesive Temperature

Metals in general are crystalline in structure, being made up of an aggregate of grains held together at their boundaries by amorphous material. In most metals at moderate temperatures, the cohesion of the boundary material is greater than the cohesion within the grains themselves, as is shown by the fact that fracture normally occurs through the grains. At high temperatures, however, the boundary material becomes weaker than the grains and fracture normally occurs at the grain

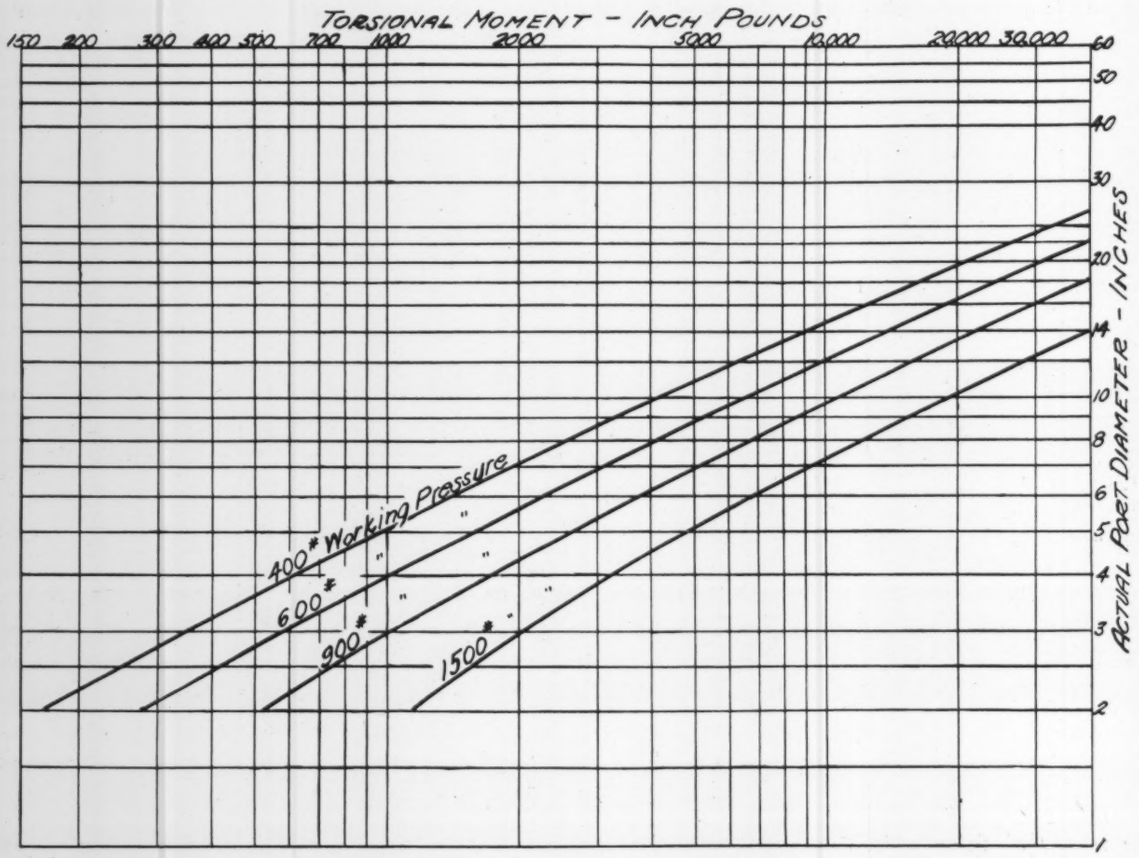


FIG. 12—TORSIONAL MOMENT REQUIRED TO CLOSE O. S. & Y. WEDGE GATE VALVES OF VARIOUS SIZES AT PRESSURE VARYING FROM 400 TO 1500 LB.

boundaries. The temperature at which the cohesion within the grains and that of the grain boundary material are equal has been called the *equicohesive* temperature. The exact location of the equicohesive temperature depends on a number of factors, but, in general, it appears to follow closely the temperature of recrystallization, and for steel usually lies in the range from 1,000 F to 1,200 or 1,300 F.

A great amount of research is being carried on at the present time, both in the laboratory and in actual service, and within the next few years it is expected that the performance characteristics of metals in the temperature zone around 1,000 F and above will be more definitely known than they are today.

Combined Effect of High Pressure and Temperature on Design, Installation and Maintenance

When we consider the combined effect of high pressure and temperature on the design, installation and maintenance of piping, we are confronted by all the familiar problems of *low pressure-low temperature* systems in greatly magnified form and, in addition to these, numerous new problems arise. The need for improvement in design, materials and workmanship is apparent. We have seen* that increasing the wall thickness beyond a certain point does not increase the strength of the container, and when the temperature is increased beyond a certain point the metals flows at a surprisingly low unit stress. These two factors call for stronger metals in the high temperature zone, the upper limit of which is constantly being raised to higher levels.

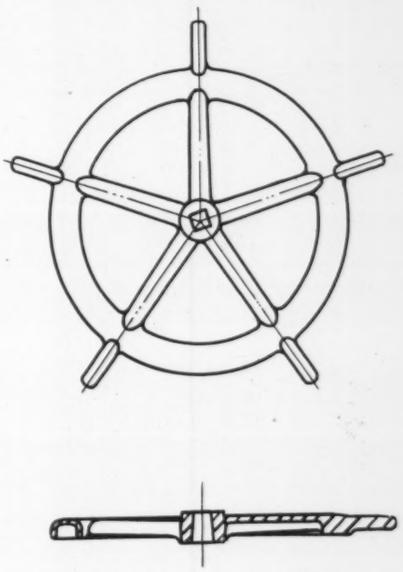


FIG. 14—TILLER TYPE HAND-WHEEL

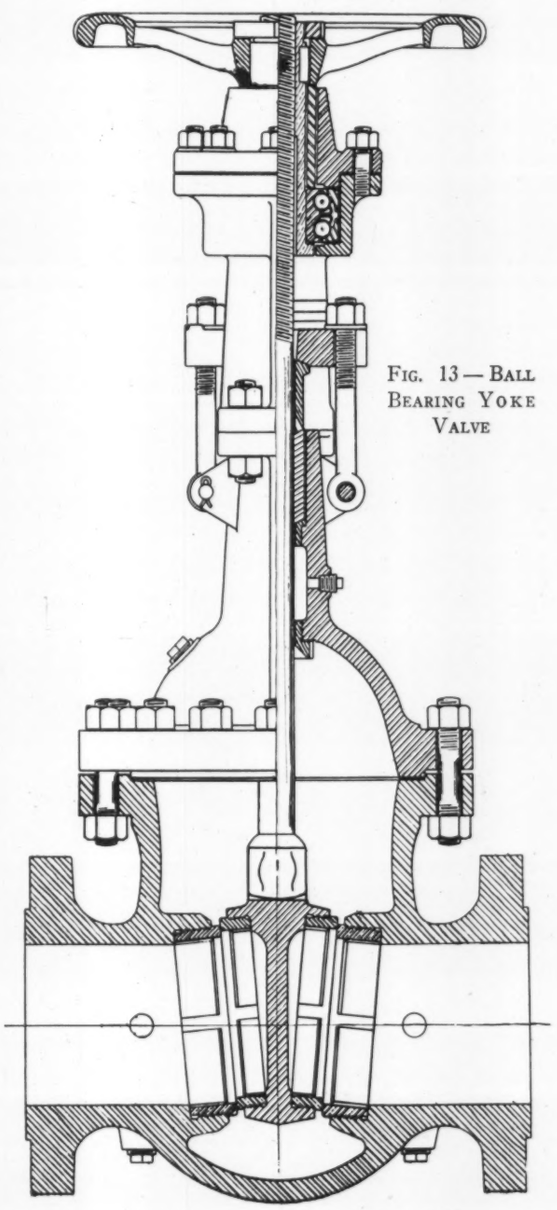
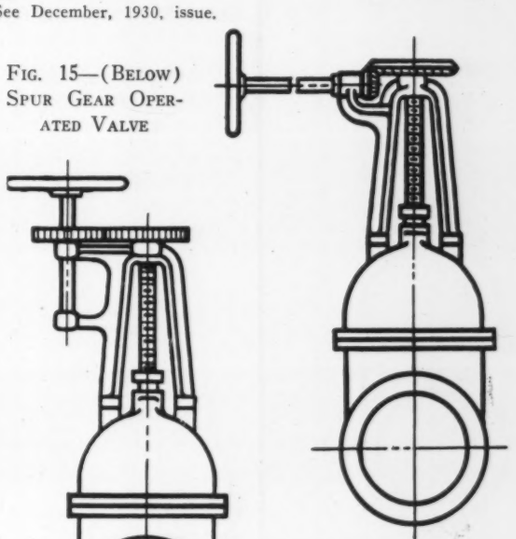


FIG. 13 — BALL BEARING YOKE VALVE

The softening effect of high temperature on metals also introduces new requirements in valve trim materials which must slide over each other under enormous pressures and, in many cases, without lubrication of any kind. Then to make the already difficult situation still more troublesome, we must also provide for the inevita-

* See December, 1930, issue.

FIG. 15—(BELOW) SPUR GEAR OPERATED VALVE



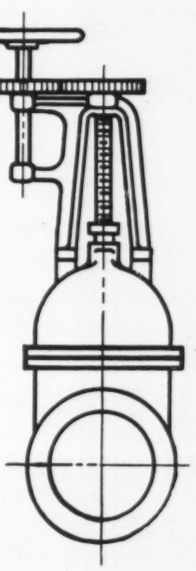


FIG. 16 — (ABOVE) BEVEL GEAR OPERATED VALVE

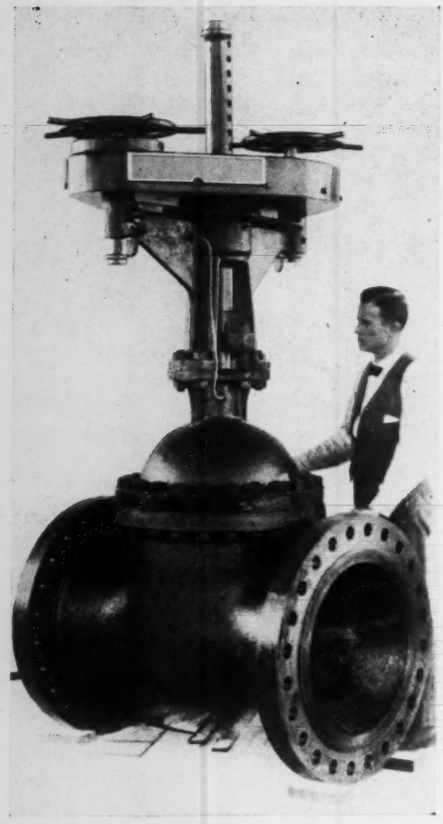


FIG. 17—AN 800 LB., 24 IN. BY 16 IN., VENTURI TYPE VALVE

FIG. 18—AN INSTALLATION OF LUBRICATED PLUG COCKS ON A HIGH PRESSURE GAS LINE

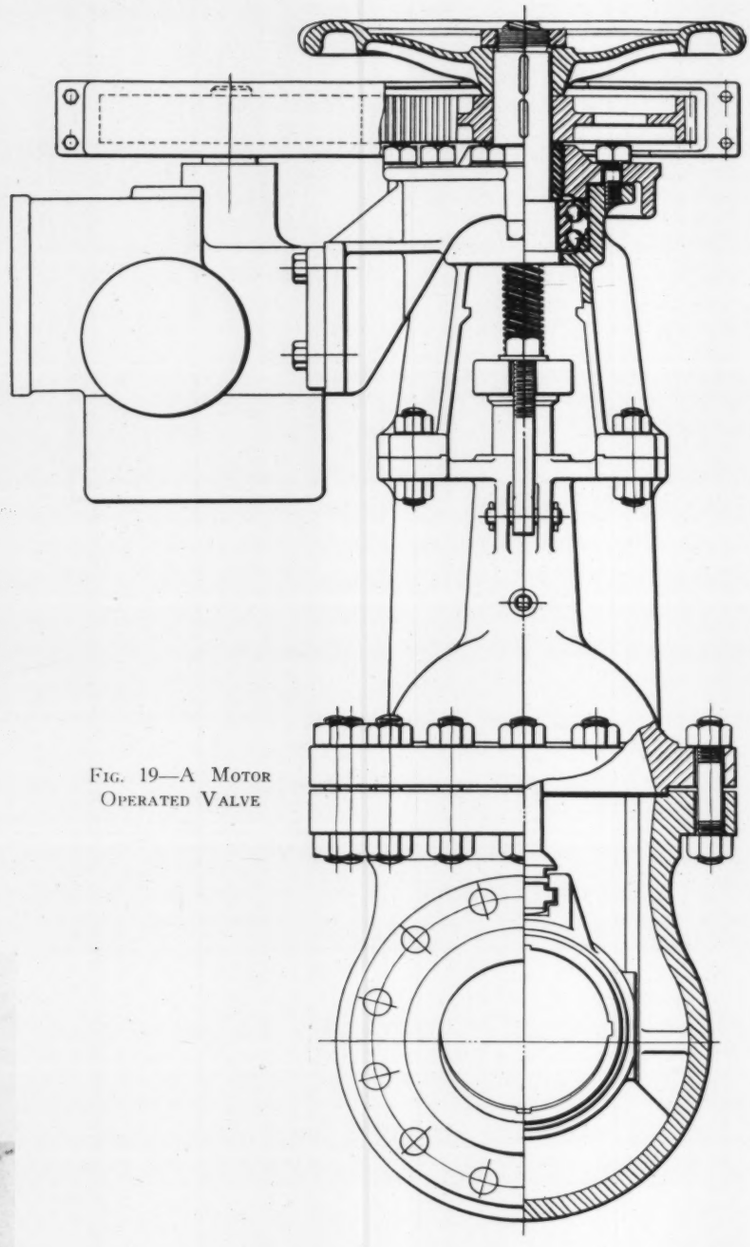


FIG. 19—A MOTOR OPERATED VALVE

ble tendency toward acceleration of corrosion by high temperature which affects trim materials very vitally and often is a factor of considerable importance in piping materials generally. Among the many details of piping layouts requiring special attention, the outstanding ones are suitable pipe joints, ample provision for expansion and contraction, proper supports, and adequate insulation to conserve heat losses, all of which become more important to the economical functioning of the piping system under the new conditions of high pressure and temperature. It is not in the nature of things that such obstacles as these could be hurdled at full speed, but it is encouraging to know that definite progress is being made.

Design Materials and Workmanship

Several years ago the general run of valves and fittings did not have a perfect record for freedom from

interior defects, and the opinion that such defects could not be avoided with certainty in steel castings was rather widespread. During the past few years, however, spurred by the increasingly severe requirements of the high pressure-high temperature service conditions that were springing into existence, great improvements have been made in steel casting design, in foundry technique

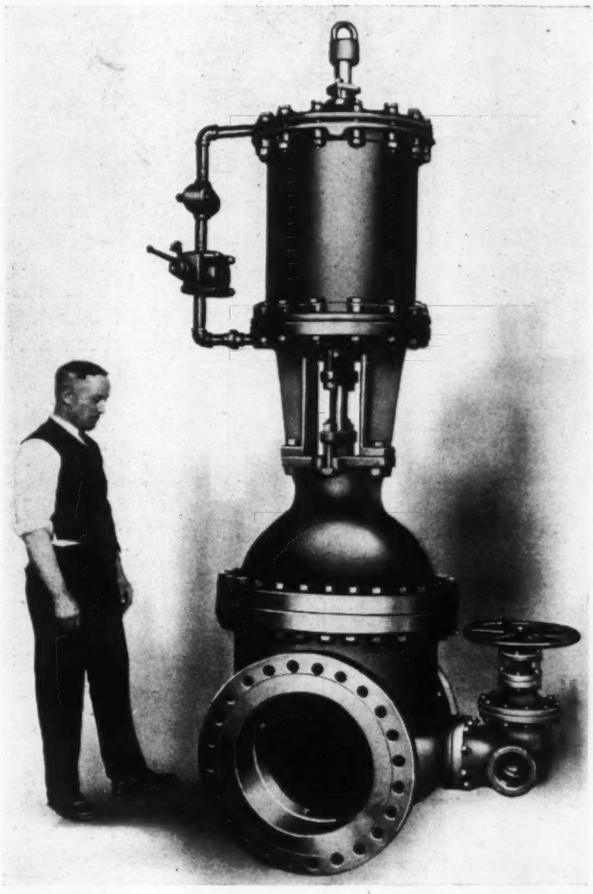


FIG. 20—AIR CYLINDER OPERATED VALVE

and in finishing operations. High voltage x-rays* powerful enough to penetrate a 3-in. thickness of solid steel have been extensively used in studying the nature and causes of the troublesome defects, and when these were fully known it was a comparatively simple matter to eliminate them by changes in design and foundry methods and establishing new standards of control, based on the new knowledge available.

* See HEATING, PIPING AND AIR CONDITIONING, May, 1930, p. 410.

Foundry Technique

These new standards for controlling the foundry technique cover such important matters as the chemical composition, melting, pouring and heat treating of the metal, the design of the casting, the heading and gating of the pattern, and the method of making and venting the mold and core. Uniformity in chemical composition is now controlled much more closely than formerly, which facilitates the standardization of processes of manufacture with assurance of uniformity in the finished product. This is particularly advantageous in connection with the process of annealing because it permits an annealing cycle fixed as to temperature and time which need not be varied to take into account variations from the standard chemical composition. This eliminates the possibility of grain growth due to over-annealing, or lack of grain refinement due to under-annealing.

The melting and pouring procedures, particularly with respect to temperatures, need to be carefully controlled. The best heat treatment for carbon steel castings to be used in high temperature service has been found to be a complete anneal which put them into a stable condition. Normalized or drastically quenched and drawn castings, while showing higher physical properties at ordinary air temperatures, undergo physical changes of structure when exposed to high temperatures for long periods, and are subject to distortion which may throw a valve seat out of alignment and cause leakage.

Long time tests have also shown the fully annealed steel to be considerably stronger than the normalized or quenched and drawn steel at a temperature of 1,000 F.

The usual defects formerly encountered in steel castings consisted of shrinkage cavities, gas and sand pockets, and cracks. Shrinkage cavities are caused by the fact that steel in solidifying and cooling shrinks approximately 6 per cent in volume, and unless the shrinkage in volume is constantly fed by additional molten metal while the casting is solidifying, a cavity is bound to result in that portion of the casting which solidifies last. The metal in contact with the mold and core solidifies first, and the central portions of the heavy section naturally solidify last, although the progress of solidification in the casting may be considerably modified by the location of pouring gates and the flow of the metal in the mold while the casting is being poured. Obviously, it is necessary to provide shrink heads of ample size to feed the heavy sections of the casting until they are completely solidified. Care must be exercised also to provide large connections between the mass of molten metal in the shrink head and the section of the casting to be fed, in order to avoid danger of freezing up the

FIG. 21—RELATIVE VOLUME OF FLUID REQUIRED FOR EQUIVALENT AVAILABLE ENERGY IN HYDRAULIC SYSTEMS

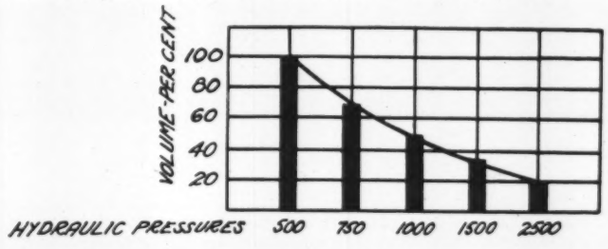
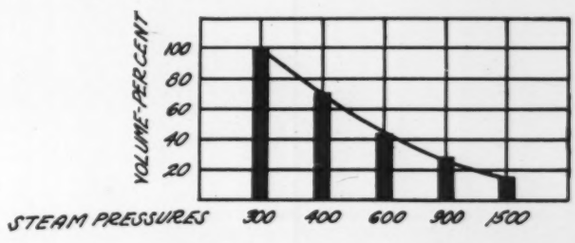


FIG. 22—RELATIVE VOLUME OF STEAM REQUIRED FOR EQUIVALENT AVAILABLE ENERGY IN MODERN STEAM POWER PLANTS



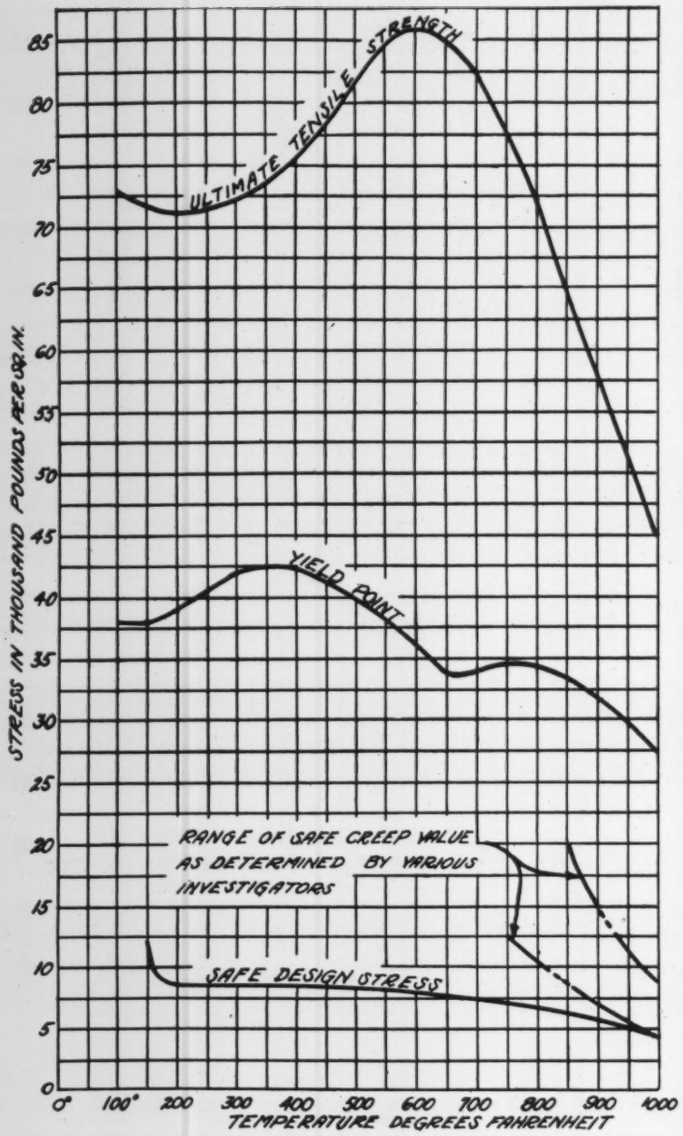

ULTIMATE TENSILE STRENGTH
YIELD POINT
RANGE OF SAFE CREEP VALUE AS DETERMINED BY VARIOUS INVESTIGATORS
SAFE DESIGN STRESS
STRESS IN THOUSAND POUNDS PER SQ. IN.
TEMPERATURE DEGREES FAHRENHEIT
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
0° 100° 200 300 400 500 600 700 800 900 1000

FIG. 23—STRENGTH AND SAFE STRESS CURVES FOR 0.30 CARBON CAST STEEL, ANNEALED

passage and shutting off the supply of molten metal before the heavy section is entirely solidified.

Figs. 24 and 25 show a high pressure cast steel tee before the shrink heads were removed and the pattern from which it was cast. Note particularly the generous fillet connecting the heavy flange section to the body wall and the adequate proportions of the standardized shrink heads which illustrate the principles involved in avoiding the formation of shrinkage cavities.

Gas pockets may be caused by imperfectly deoxidized metal, or by gas which enters the metal from the mold or core, and defects of this character may be easily avoided by standardized foundry control methods. Pockets containing both gas and sand are caused by loose dirt in the mold and plain sand inclusions are usually caused by cutting of the gates and runners, or washing of the mold. Standardized foundry control will also eliminate defects of this character.

Cracks are caused by linear shrinkage and the danger of producing cracks is readily apparent when it is realized that a casting such as shown in Fig. 24, which is 30 inches in over-all length, shrinks approximately $\frac{5}{8}$ of an inch during solidification and cooling, and in order to do this the metal must be strong enough to crush the mold. The strength of the metal is of course very limited, due to its exceedingly high temperature when the casting first begins to shrink, and the mold consequently must be so constructed that it will readily crush without cracking the casting. This condition, too, is readily taken care of when the casting is not too complicated, but foundry problems of this character sometimes are rather troublesome.

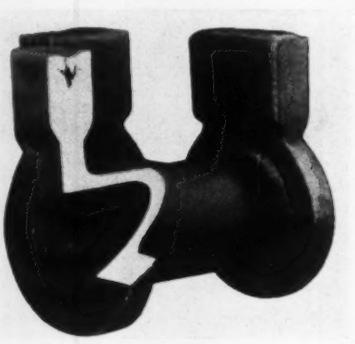
Welding Often Used

If a casting is to be made in quantity, the development of the necessary technique may be absorbed in the over-all cost, but if only one or two castings are required the cost of the preliminary work may greatly exceed the value of the castings. A standardized foundry technique has been developed for the American Standard fittings patterns and their use is, therefore, strongly urged. Where special fittings, such as long manifolds and headers, are necessary, welding often offers a reliable and economical method of construction. With the newly-developed methods of welding and welding control methods, it is possible to produce strong and ductile welds and a great many high pressure-high temperature containers of this type are now in successful operation.

Standardization Work Should Be Supported

The highly commendable work of the U. S. government, the *American Standards Association,* the *American Society of Mechanical Engineers,* the *American Society for Testing Materials,* the *Manufacturers' Standardization Society of the Valve and Fittings Industry,* and other organizations, in promoting the standardization of product and materials and in eliminating unnecessary sizes and types of product, should be enthusiastically supported, because this program not only helps to improve the quality of the products, but also tends to lower the cost of production, distribution, installation and maintenance.

FIG. 24—400-LB. WORKING STEAM PRESSURE CAST STEEL TEE WITH SHRINK HEADS ATTACHED



Workmanship is equally as important as design and materials in manufacturing and much improvement has

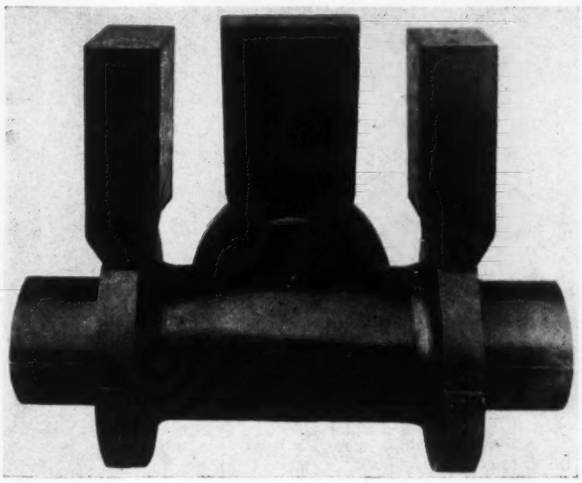


FIG. 25—PATTERN FOR 400-LB. WORKING STEAM PRESSURE CAST STEEL TEE WITH STANDARDIZED SHRINK HEAD

been made in recent years in the quality of the finishing operations on high pressure-high temperature products. Powerful and rugged finishing tools are used to assure precision work, more attention is paid to allowances and tolerances so as to provide proper fits of mating parts, and careful inspections and tests are made to keep the quality up to standard.

Care Should Be Exercised by Users of Valves

Manufacturers of high pressure valves use great care in seeing that the valve is properly made and tested and that when it is shipped to the customer it is properly crated to protect it during shipment. In view of the fact that a high pressure valve may be completely ruined by a single cut or scratch across the valve seat, the users of these valves should employ equal care in handling them in order to make sure that the valve will give satisfactory performance when it is placed in service. The conditions on the job are not always conducive to the proper care and handling of high pressure valves, but treatment such as illustrated in Fig. 26 should not be permitted.

New Steam Tables and Mollier Diagram for High Pressures Announced

Recognizing the need of authoritative steam tables for use in steam power engineering design in the pressure range up to 3,200 lb. per sq. in., "Steam Tables and Mollier Diagram" has been published by the *American Society of Mechanical Engineers.* The author is Joseph H. Keenan, assistant professor of mechanical engineering at the Stevens Institute of Technology. The tables include the results of recent steam research, which has been extremely active and has been international in scope. The sources and methods of developing these tables were detailed in *Mechanical Engineering,* the journal of the A. S. M. E.

Superheated Steam Table to 3,500 Lb. and 1,000 F

Table 1, for saturated steam, covers the range from 32 F to 706.1 F. Table 2 is a pressure table for saturated steam from 0.20 lb. per sq. in. to 3,226 lb. The superheated steam table goes to 3,500 lb. per sq. in. pressure and 1,000 F temperature. Conversion tables, logarithmic tables, etc., are also included in an appendix.

Mollier Diagram

A Mollier diagram for the high pressure and high temperature ranges accompanies the sixty-four page volume. The book is bound attractively, and is approximately 7½ by 10½ inches in size. It may be purchased from the Publication Sales Department of the *American Society of Mechanical Engineers,* at 29 W. 39th st., New York City.

FIG. 26—ABUSE OF VALVES ON THE JOB MAY CAUSE UNSATISFACTORY SERVICE

Practical Results *of* Air Conditioning in Textile Mills

By James W. Cox, Jr.*

THERE are many manufacturing reasons why conditioned air is necessary in textile mills, which reasons, perhaps, may not be the same as those in other industries, such as, for instance, chemical, candy, baking, etc. The one principal reason, however, in the textile industry (as in others) is purely economic, i.e., to humidify a textile mill properly results in consistent, permanent financial gain. If this were not the case, it is doubtful whether the use of humidifying equipment would have become as widespread in the textile industry as it is today.

Generally speaking, proper air conditioning in the various departments of many types of textile mills has proved definitely three essential facts which have been of great value, these being greatly improved operation, enhanced quality (and therefore value) of the product made, and a reduction in the net final cost per pound or per yard.

Air Conditioning Not Accepted Generally

It should not be assumed by any means that the value of proper conditioned air is appreciated generally throughout all branches of the textile industry. The majority of all textile mill operators do not realize fully the benefits which can be derived by properly humidified or conditioned air in those departments where it may be more or less of a factor in processing. This generally is in such mill departments as carding, spinning, yarn, weaving, knitting, braiding, etc. It does not affect vitally many of the finishing[1] departments.

The proposal to install additional equipment in a long established plant usually brings forth many objections.

Some of the unreasonable and unjustified, but nevertheless sincere objections, are that the installation of an air conditioning system costs too much, hinders the operation of machinery, hinders the work of the employes, slows up processing, makes poorer work, makes wet floors, causes accidents, is not healthful on account of dampness, that this "dampness" is as bad as "old fashioned" air and, therefore, causes rheumatism and finally that it is not necessary because the industry has never had it before and has grown without it for 200 years.

Acceptance Varies with Branch of Industry

Practically all cotton spinners, weavers and rayon manufacturers have accepted the maintenance of proper temperature and humidity as essential for the production of consistently good products, and practically every plant of the above types is equipped more or less with humidifying or conditioning apparatus. This is also true of worsted "top" makers[2] and spinners, but temperature and humidity are not controlled in all of the processes.

Silk manufacturers, particularly the throwsters (spinners), and cotton knitters are convinced somewhat as to the value. Therefore, humidification systems are in more or less general use in mills of these types.

On the other hand, humidification is not considered necessary by many woolen, merino, felt (pressed or woven) or jute manufacturers. It has been accepted and used by some, however, with remarkably good results.

The bleaching, dyeing and printing branch of the industry, i.e., the finishing trade as a whole, has not yet accepted the basic principles though there are some notable exceptions to this rule where the use has been very profitable.

Flax, hemp and sisal products are manufactured in such comparatively small quantities in this country that some consider them of minor importance to the industry as a whole.

How Moisture Affects Raw Materials

In explaining the principal reasons conditioned air is used in textile mills, it is felt that a brief resumé should be given as to how moisture affects the raw materials used.

There are nine main types of textile raw materials used commercially in the textile industry through the world. There are others, of course, but they are of minor importance. The principal materials listed in what is considered by most textile men in their order of importance, are as follows: cotton, wool (including mohair, alpaca, camel hair, cow hair, rabbit fur, etc.), silk, rayon, flax, jute, hemp, sisal, asbestos.

From the above list it can be observed that six—cotton, rayon, flax, jute, hemp and sisal—are of vegetable origin, basically cellulose, where as two—wool and silk—are of animal origin and one—asbestos—of mineral origin. It should be remembered that all but two are naturally in short lengths (fiber form), whereas silk and rayon are in continuous strands of very long length (filament form).

With the exception of asbestos, all raw materials because of their nature, whether fiber or filament, have a definite normal, natural moisture content. Bitter experience has proved that when any of these raw materials are deprived of part of this natural, normal moisture content, they invariably tend to become stiffer, more brittle, less pliable, have less strength and in general can

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[1] The *finishing department* of a mill is that department which gives the final appearance to the cloth to make it saleable for the purpose intended, i.e., bleaching, dyeing, mercerizing, "fluffing-up," ironing out, stiffening, softening, etc., as may be necessary.

[2] A *worsted top maker* is a concern in the worsted branch of the trade that takes wool as it comes off the sheep's back, scours it and prepares it in a form for worsted spinning.

not be processed, as well, as cheaply or with such good results as when in a normal moisture equilibrium. On the other hand, wtih the exception of rayon and jute, their inherent natural qualities are not changed to any important extent by the addition of excess moisture.

Rayon and jute, however, become more plastic, stretch more, and weaken materially when they contain more than the normal moisture content.

The amount of moisture content in any particular type of fiber or filament mentioned above under right temperature and humidity conditions, does not vary much from a hydroscopic standpoint. The various materials, however, do vary in hygroscopic[3] qualities. It is quite obvious, therefore, that it is important to maintain the normal amount of water in the various fibers or filaments and in the case of jute and rayon, not to have more than a normal amount.

Definite Atmospheric Conditions Vital

In processing these raw materials from the original state to the finished fabric, very light fibers or filaments are drawn through the air in various types of machines. The heat generated in certain machines sometimes is relatively great. There is a tendency, therefore, to evaporate or give off moisture and, if possible, this must be prevented or the stock is impaired in quality or partially broken. This is prevented by having the air in and through which the stock is being processed, at such a temperature and relative humidity that the equilibrium of moisture between stock and air is not overbalanced causing a flow from stock to air but that it is slightly the other way, thus assuring the proper amount of moisture being retained in the stock.

It can be realized, therefore, that proper atmospheric conditions in any room in or through which textile materials (with the exception of asbestos) are being processed, must be maintained at a predetermined temperature and relative humidity, as by so doing the three conditions mentioned at the beginning of this article are influenced and better operation, better quality and reduced cost are obtained.

[3] As used here, the word "hydroscopic" refers to a fiber's characteristic normal or regular moisture content, i.e., an amount which is a certain per cent of its weight.

"Hygroscopic" refers to a fiber's characteristic or natural tendency to give off or take up moisture under certain conditions.

In other words, "hydro" is the amount and "hygro" is the way the fiber takes up or gives off moisture.

Results Obtained

More specifically, the primary benefit due to proper humidification of air in the operation of a mill are basically greater production, higher and more uniform quality, fewer "seconds,"[4] less waste, greater strength, better wear, superior finish (appearance), better retention[5] of finish and finally lower cost.

The secondary benefits are improved working conditions from an operative's standpoint, since properly humidified air is healthier, better ventilation is obtained, cooling in summer is secured (this being vital in Southern cotton mills), and the work is easier for the operatives because of better running. This results in higher wages on piece work, less turn-over and more contented employes.

A third factor, oftentimes not considered, but of great importance, is that raw materials are purchased with a certain amount of moisture content, and if the finished product is sold with less there is a definite loss in poundage, because of this alone, which is reflected directly in money, sometimes amounting to $75,000 a year, in a medium or large size mill.

Troubles in new installations have been many for various reasons. Invariably they have been caused primarily by lack of knowledge of the whole subject and secondly by improper equipment, improper operation of equipment and lack of maintenance of the right temperature and humidity conditions even if the equipment were of the right type and capacity. Such troubles are becoming less common as our knowledge increases.

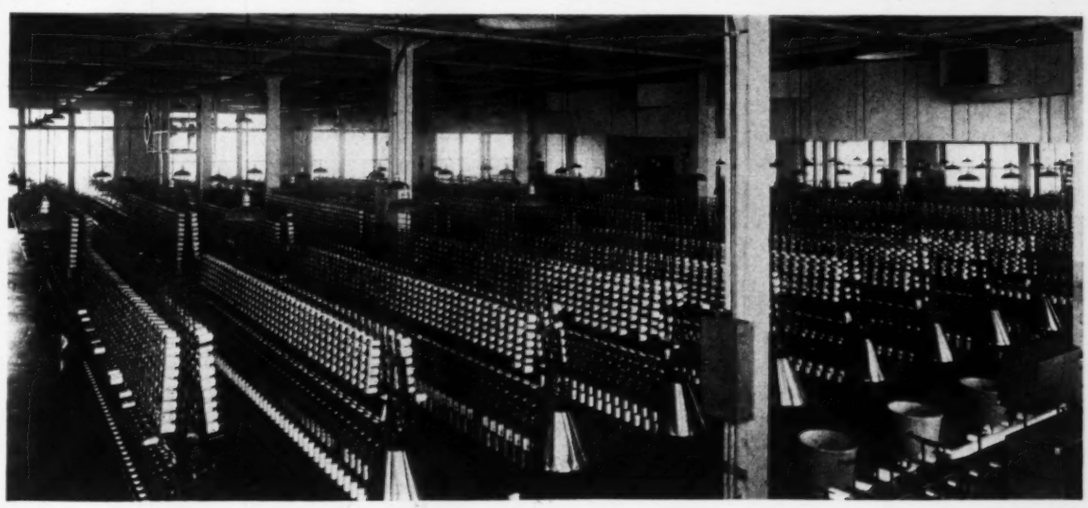
Conclusion

The deep-seated prejudices of some mill men are disappearing rapidly and it is the opinion of the writer that in another ten years practically no textile mill will be able to make money consistently without proper humidifying equipment.

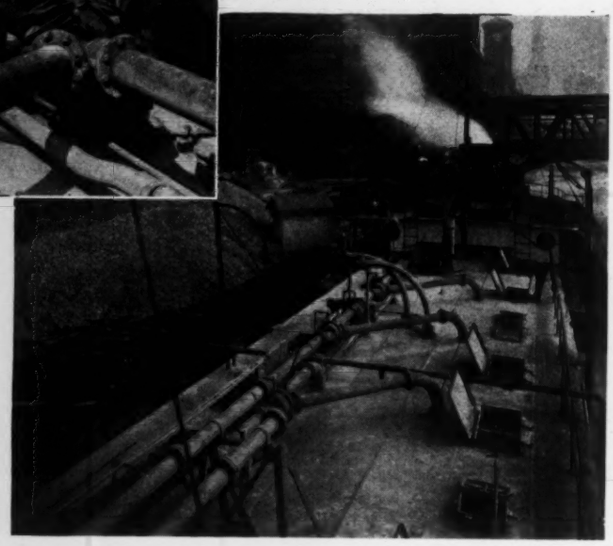
There have been very great strides in improving equipment, particularly during the last few years, but there still is room for more improvement. To those engineers who can contribute to the improvement it is certain that from a financial standpoint the opportunities will be very bright.

[4] *Seconds* are those goods, materials, etc., which for some reason or other are not up to a predetermined standard of quality, are spoiled, injured and, therefore, lessened in value some way. In other words, they are not first or best quality goods.

[5] *Retention* means the retaining or keeping in the "finish." In other words, the holding of the original appearance of the cloth as shipped to the consumer.



Piping Used to Unload Finely-Ground Products



PORTLAND CEMENT BEING PIPED FROM THE DANIEL MCCOOL FOR FOOTINGS AND FOUNDATIONS FOR THE MERCHANDISE MART. THE VIEW TO THE LEFT SHOWS THE OPERATION OF ONE OF THE TWO-WAY VALVES

FOR the making of concrete for the foundations and footings of the Merchandise Mart at Chicago portland cement was conveyed at the rate of two million pounds in seven hours by means of a piping system from a ship at the Mart dock to a hopper about 65 feet high, near the wharf. The vessel (the *Daniel McCool*) shown in the illustration was the first of its kind in service on the Great Lakes, and is equipped with cement pumps, air compressors and the necessary standard piping.

The method here illustrated is used in the conveying of finely-ground manufactured products, portland cement, bone ash, talcum powder, powdered coal, pulverized lime, gypsum, soda ash, bauxite, manganese dioxide, pulverized starch and other dry, pulverized materials. Such materials are quickly conveyed from boats, railway cars, trucks and the like, to silos, mixer bins, storage bins, etc.

In the equipment shown, one moving part, with one drive, performs the three functions of conveying, elevating and distributing. The cement conveyed from the vessel to the Mart was first advanced through and compacted in the pump barrel by a rapidly rotating impeller screw. Slightly beyond the pump screw, a small volume of compressed air was continually admitted to create a fluent mixture of air and cement, which was forced through pipes 5 in. in diameter. Part of the piping system, as will be seen in the illustration, is of flexible rubber hose. In some uses, the piping is buried under ground, so as not to interfere with highways, railroads, buildings and machinery, or it may be supported overhead by pipe hangers.

The equipment comprises a pump, which forces the material through a pipe line under pressure, a conduit of pipe, automatic or hand operated switching valves for diverting the flow of material to any desired receiving receptacle, and a source of compressed air to be admitted through the pump for aerating the material to make it fluent, in which state it is conveyed. Automatic or remote control switching valves are used, where frequent diversions of material are required.

A part of the equipment used in the boat consisted of two 8-in. pumps, each directly driven through a flexible coupling by a 75 hp. motor. Two 5-in. pipes, into which the pumps discharge, rise vertically to the deck and have flexible hose connections suspended on a davit for attachment to shore lines. The cement is loaded in the boat by pumping through similar systems. The 5-in. transport lines carry the cement from the storage silos at the cement mill to the dock, a distance of 475 feet. Branch lines distribute the cement to the bins on board.

The cement was stored in the boat in two rows of steel bins, from which it was discharged to the cement pumps by means of small longitudinal collector screws. Compressed air is admitted to the discharge end of the pumps at a pressure of about 80 pounds. The back or transport line pressure of the cement in the pipes on shore is usually about 20 pounds.

A small compartment forward of the conveyor room contains two cement packing machines, to enable the delivery of bagged cement at ports where receiving bins are not available. Dust from the packing machines and other sources is collected by filters, exhausted by two fans.

It will be observed from the illustration that, except for the hatches and unloading pipes, the deck is quite clear.

The boat is loaded by means of two 5-in. pipes which have their inlets at the forward end of the deck, one for the forward compartment and one for the after compartment. Two-way valves enable the operator to place the cement in the particular compartment required.

In order to reduce friction, long sweep L's are used on the discharge line bent on a radius of 6 feet. The amount of air is apportioned to the weight of the materials. In conveying portland cement on this job, the amount of air and cement bore a ratio of about 1 to 10—that is, one part of air to ten parts of cement.

Selecting Sterilizers

Article No. 1

By Rollo E. Gilmore*

STERILIZERS are designed as a means of killing germs, microbes, and minute pathogenic organisms or spore bearers, thus preventing infections. Much inconsistency in the use of the word *sterile* is to be found, but it is generally conceded that an exposure of five minutes in moist steam at 15 pounds or at a temperature of 250 F will destroy all germs and their spores in the case of water in a sterilizing tank or the contents, such as instruments, basins, or glassware. However, to make doubly sure, longer treatment periods are recommended.

In dressing sterilizers, the sterilization of cotton goods is governed by the size of the packages and the degree to which these packages are compressed when pinned in such form, or when packed in drums. To overcome the resistance of steam or heat penetration or lag in temperature or pressure, due more to air than to anything else in the sterilizer, it is first essential to create a vacuum or evacuate the air by forcing it out by steam pressure, and then to subject the goods to steam pressure at 20 pounds, or 259 F, for one hour or less, depending on the size of the packages.

Steam at less than 20 pounds pressure may not penetrate to the center of a lap package, which is about one cubic foot. Steam at more than 20 pounds pressure, especially if dry, may discolor cotton goods. The most modern equipment should be selected to safeguard the health of patients, provide safety to its operators, and neatness in its appearance.

Dressing Sterilizers and Autoclaves

The cylindrical dressing sterilizers and autoclaves are generally referred to as the pressure type; they are very satisfactory, especially for built-in concealed construction. In addition to being used as dressing sterilizers and autoclaves, they are adapted for use as pressure instrument and pressure utensil sterilizers.

These pressure sterilizers, designed to sterilize dressings, sheets, towels, gowns, instruments, basins, trays, culture media, serums, laboratory glassware, etc., consist of thick double walls and steam jacketed chambers with doors designed to be securely bolted by means of radial locks to automatically throw steel fingers, making them steam and vacuum tight. The shells usually are seamless drawn for both inner and outer jackets, although some manufacturers fabricate shells. The shells are riveted and sweated to cast bronze end rings. Doors are of cast bronze with groove and endless ebonite gasket. Special ejectors or vacuum devices, both manual and automatic, are used to withdraw the vapor and to hasten the drying process.

Experiments have indicated that the system of creating a vacuum before sterilization required an excessive amount of energy, in that some air remained in the dressing chamber, with the result that there were hot air pockets after steam was emitted. Some type of safety device should be provided to prevent the opening of the door when the sterilizer is under pressure. Jackets should be insulated. The height from the floor to the center of the horizontal cylindrical sterilizers should be approximately 45 inches to 48 inches. A vertical type autoclave is also made of 6, 8, and 10 inch diameters by 12 inches in depth, which is especially for chemical use.

A safety gage glass control with guards is desirable where the generator or sub-boiler type is used. In the general laboratory, the steam single wall autoclave should usually be selected, although occasionally the jacketed type sterilizer is used. Culture media and solutions should be sterilized without the vacuum device, but with glassware and cotton, following sterilization, the aid of the vacuum device is necessary. Laboratories where fluids are used exclusively should be equipped with single shell autoclaves in which no vacuum can be provided. The creating of a partial vacuum within the chamber loaded with flasks of solutions will cause the contents to boil away and result in a loss in the fluid volume.

Experience indicates that steam for sterilizing should

* Vice president, Chicago Association of Consulting Engineers; engineer, Schmidt, Garden & Erikson, architects.

This is the first installment of Mr. Gilmore's review of sterilizers and water stills, in which the author shows the trends in their construction and use today, with a discussion of desirable sizes, and of proper installation.

It is an article written for the consulting engineer doing hospital work, for the chief engineer of the hospital, and for the engineer of the laboratory; or the hotel, the apartment, and industrial plant which maintains a private or emergency hospital.

Information on required temperatures and pressures, steam and electric consumption, and on characteristics of various type sterilizers will be found herein.

be moist, saturated, not superheated, as dressings, gowns, towels, etc., should be wet for efficient sterilization. Moist steam sterilizes at approximately 250 F, whereas dry air sterilizers must operate at 347-400 F, for equal efficiency, for a period of at least an hour. In hot, dry air it has been found that some germs assume the spore form, as anthrax, and are highly heat-resisting, excepting in the presence of moisture.

A small steam separator, installed on the steam inlet, is advisable in connection with the pressure sterilizers, mainly to separate the oil before it comes in contact with the contents being sterilized. The pressure instrument sterilizers should be of the double jacketed type with a vacuum device and equipped with removable sliding trays for sterilizing surgical instruments and gloves.

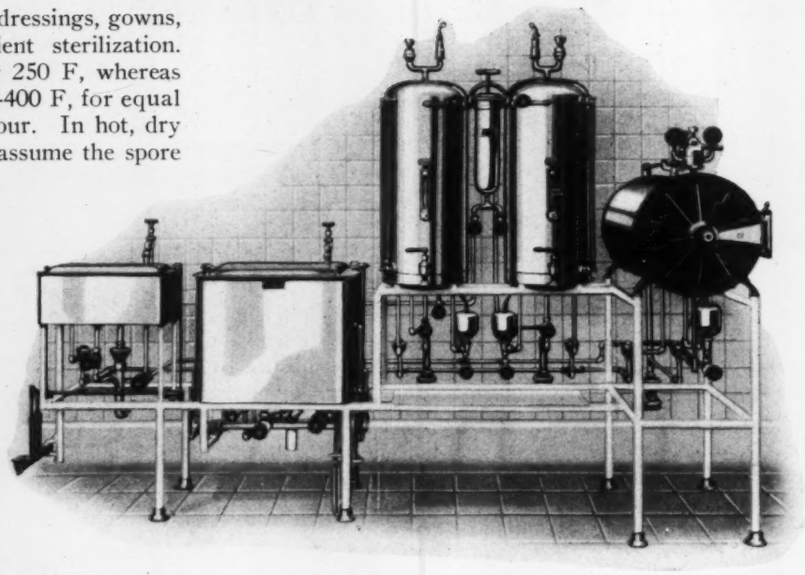


Fig. 1—Front View of a Battery of Sterilizers

Sizes of Cylindrical Pressure Sterilizers

The sizes of cylindrical pressure sterilizers are debatable to a certain extent, but for general aid the following will be found useful:

For small surgeons' offices, a small operating room, or a laboratory, to accommodate flasks for sterilizing water or saline solutions, small packs of dressings, gowns, racks of media or serums, or small basins, the 10-in. diameter by 20-in. length, containing approximately 1,570 cubic inches or 12-in. diameter by 20-in. length, containing 2,260 cubic inches, or the 14-in. diameter by 22-in. length, containing 3,388 cubic inches, or the 16-in. diameter by 24-in. length, containing 4,825 cubic inches, are the minimum cylindrical pressure sterilizers generally selected. However, the 8-in. diameter by 16-in. length autoclave sterilizer, containing 800 cubic inches, has met the demands of some of the smaller surgeons' offices and emergency operating rooms.

For the hospital having one major and one minor operating room, a 16-in. diameter by 24-in. length (containing approximately 4,825 cubic inches) cylindrical pressure sterilizer is the minimum size generally selected for the sterilizing of surgical instruments, dressings, gowns, and utensils, and will take care of one operating room having a maximum of two or three operations per day; for greater capacity this proportion should be used selecting one or more of the pressure sterilizers. There are many factors making it difficult to lay down a rule. For instance, a medical hospital or surgical hospital of the same bed capacity would vary. For the larger hospitals where a large number of surgical cases are anticipated or known, the following sizes are suggested:

Diameter, In.	Length, In.	Cubical Contents Cubic In.
16	36	7,236
16	48	9,648
16	60	12,060
20	28	8,792
20	36	11,304
20	48	15,072
20	60	18,840

A 16-in. by 48-in., or equivalent size, pressure dressing sterilizer should sterilize all materials used in a busy major and minor operating room.

Built-in Sterilizers

The recessing or building in of sterilizers eliminates much excess steam and heat from the sterilizing room, and as the hospitals have grown, large rectangular pressure-type dressing sterilizers, similar to the sterilizers formerly used exclusively for mattress and similar disinfecting have become popular. They are usually used once or twice a day, rather than have a smaller sterilizer operate continuously. Many hospital institutions and manufacturers of cotton use this type of sterilizer for bulk sterilization of gauze, cotton, sutures, etc., as they can be used for bulk sterilization in packages or drums or a mixture of the two. This sterilizer is now designed in smaller sizes, in width, height, and length for recessing or free standing in a sterilizing room, as desired.

It is sometimes equipped with a carriage; the capacity is equal to that of several pressure type cylindrical drum dressing sterilizers. In hospitals the sterilizers of this type are usually placed in a central sterilizing room or the nurses' work room. Standard sizes range from a 24-in. diameter to a 60-in. diameter and the rectangular from 24 inches by 24 inches to 52 inches by 60 inches, the lengths being 36 inches and up.

Where cylindrical dressing sterilizers are used, drums of 14-in. diameter for the 16-in. diameter dressing sterilizers are commonly used and are usually preferable to those of larger diameters. It is feasible, however, to employ sterilizers of very large diameter using sliding carriages holding more than one roll or drum in width.

In any event the installation should include a sufficient number of sterilizer drums with spares to take care of the wants of the entire hospital. It is advisable in connection with central sterilizers to equip them with automatic recording gages for keeping a graphic record of each sterilization. There are also many other automatic devices available for regulating and safeguarding the sterilizing processes which can be used with value.

Pressure dressing sterilizers and instrument or utensil sterilizers and autoclaves of the cylindrical pressure type should have steam supplied at forty-five or more lb. per sq. in., reduced to maintain twenty pounds steam pressure, corresponding to 255 to 268 F for a period of thirty minutes during the sterilizing period or cycle. This will require a steam consumption of approximately the following:

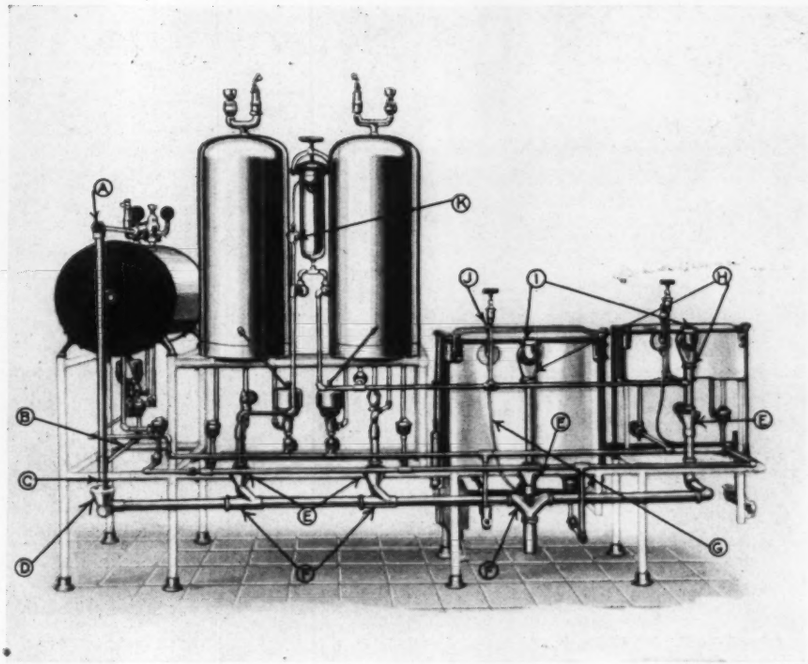


FIG. 2—REAR VIEW OF A BATTERY OF STERILIZERS, SHOWING THE PIPING. *A*, OUTLET FOR DISCHARGE OF EXHAUST STEAM AND AIR FROM CHAMBER. *B*, AIR AND CONDENSATION OUTLET INTO VENT AND WASTE. *C*, FLASH TRAP HERE PREVENTS ESCAPE OF STEAM INTO ROOM. *D*, OPEN FUNNEL IN WASTE. *E*, OPEN FUNNELS. *F*, WASTE FITTINGS DESIGNED TO FACILITATE FREE FLOW. *G*, LEAKAGE DISCHARGE PIPE FROM WATER FILL. *H*, WATER OVERFLOW OUTLET. *I*, ATMOSPHERIC DISCHARGE OUTLET FOR EXCESS STEAM. *J*, SANITARY WATER-LINE—VENTURI TYPE. *K*, FILTER TELL-TALE.

DIAMETER, IN.	LENGTH, IN.	STEAM CONSUMPTION LB. PER HR.	
		MINIMUM	MAXIMUM
12	20	6	35
14	22	7	40
16	24	7	40
16	36	9	50
16	48	12	70
16	60	15	80
20	28	10	70
20	36	10	75
20	48	12	80

With electric heating the pressure sterilizer should, of course, be equipped with sufficient electric heating elements. The electric current consumption, based upon the steam pressure being maintained at 18 pounds during removal of the dressings, and switch at high heat for 30 to 45 minutes, and on medium heat for 30 minutes, with drying period of 15 minutes, is shown in the table in the next column.

ELECTRIC CURRENT CONSUMPTION OF STERILIZERS

DIAMETER, IN.	LENGTH, IN.	MAXIMUM WATTS	CURRENT CONSUMPTION KW-HR. PER PERIOD
12	20	3,000	3.6
14	22	5,000	5.5
16	24	6,000	6.0
16	30	6,000	6.6
16	30	6,000	7.2
16	48	10,000	11.0
16	60	10,000	12.5
20	28	10,000	9.0
20	36	10,000	10.0
20	48	15,000	15.0

Drum Sterilization

In some hospitals the surgical dressings are wrapped in small bundles or packs and then packed in the autoclave type sterilizer. This method permits the operator to utilize the space in the sterilizing chamber and get more dressings sterilized at one time, but it results in a loss of time in handling. Some have adopted wire baskets to facilitate this handling.

A method which is generally used consists of dressing drums into which the dressings are placed, and the drums and contents are then placed in the sterilizing chamber. Upon the completion of the sterilizing period the drum is removed and the sterile dressings are usually carried to the operating room or patients' bedside. These drums are made of heavy copper, tinned inside and plated outside, in diameters from one to two inches smaller than the inside diameter of the cylindrical dressing sterilizers and having an approximate depth of eight inches. Where drums are used, a drum container cradle carriage or conveyor lined with a tinned brass screen is desirable. The drum carriage should have ball bearing rubber-tired wheels and a retaining latch. The drums should be so designed that halves can be rotated one within the other so they can be made open or closed receptacles.

The second part of this paper will appear in an early issue.

Smoke prevention advice usually concerns, first, better methods of firing, and second, fuels which produce less smoke. Efforts in this direction only can alleviate the nuisance usually and can not effect complete elimination. A way of accomplishing this is to collect the solids in the flue gas at the source. Two general types of equipment for doing this are mechanical collectors, such as the ordinary cyclone and an induced draft fan both placed between the boiler and the stack, and filters.

Bag filters can be used successfully; asbestos bags often eliminate the necessity of cooling the stack gases.

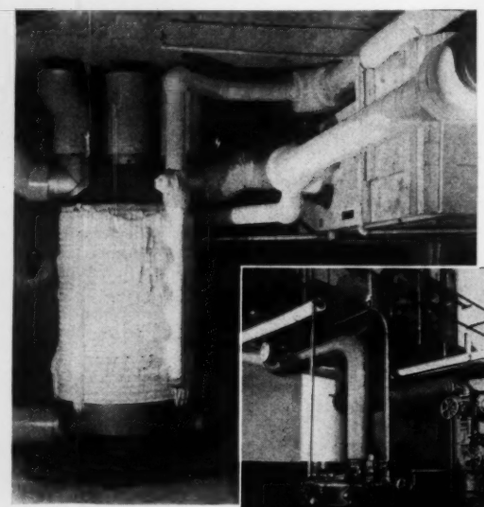
The size of the equipment is governed by the volume of flue gas. This volume is difficult to measure without special instruments, but can be estimated from the maximum amount of coal per hour, and the CO_2 content of the gas.

Humidity Controlled in Produce Terminal

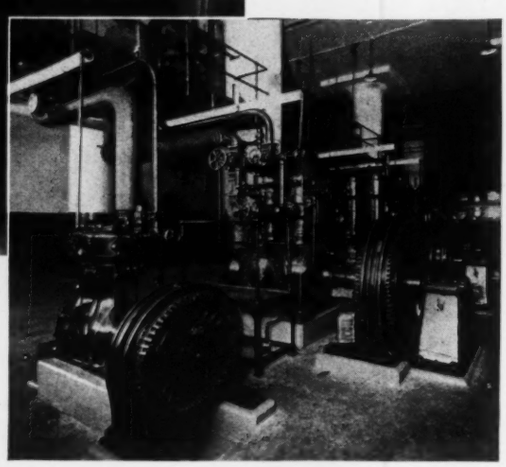
By Clarence E. Baker*

THE city of Philadelphia now claims one of the world's largest and most modern railroad terminal plants devoted exclusively to the handling of fruits and vegetables, the Pennsylvania produce terminal. This plant was recently constructed by the Pennsylvania railroad to care for the increasing demands for the rapid handling of perishable produce arriving in the city for distribution through the produce trade.

Refrigeration for this warehouse is furnished by three 123-ton and one 28-ton ammonia compressors, which will take care of any future enlargement of storage capacity without the installation of additional equipment. The plant has been operating on a basis of 30,000 cubic feet of storage space per ton of refrigeration supplied. Each of the large compressors is driven by a 175 hp. motor and the small compressor is driven by one of 50 hp., all direct connected.



THE AIR CONDITIONING SYSTEM PERMITS THE USE OF OUTSIDE AIR WHICH IS HUMIDIFIED, OR DE-HUMIDIFIED TO THE PROPER DEGREE BY PASSING IT THROUGH A REFRIGERATED COIL



THE MACHINE ROOM, SHOWING THE ARRANGEMENT OF THE COMPRESSORS AND MOTORS

Cold Water from Wells

Cold water is furnished by two wells 385 feet deep and 500 feet apart. These wells were drilled especially for this purpose and are capable of supplying 700 gallons of water per hour each. The temperature of this water runs about 52 F the year round, making the condensation problem a simple one. Shell and tube condensers with large cooling surfaces are used which, with the low temperature of water, makes it possible to operate the system on a gage back pressure of 120-125 pounds and a suction pressure of three to five pounds when operating on simple compression and three to 23½ pounds when operating the booster. These wells cost $12,000.00 each to drill but they are considered to be a good investment as they furnish an abundant supply of water at a temperature considerably below that of the city water supply and the water can be pumped very cheaply. This means that the ultimate cost of the water is far below that for the required volume of city water to do the same amount of work.

Operation of Compressors

In going suction pressures may be varied and the compressors are arranged so that they may be operated either on simple compression or on a booster compression system, similar to two-stage compression. Any two of the compressors may be used, as owing to the by-pass reduction devices upon the compressors, any desired load condition can be met in operation either way.

Control of Brine Flow

Circulating brine is piped to all of the storage compartments and a brine temperature of —8 F is maintained as the brine leaves the engine room. The temperature of the brine leaving the supply tank and the temperature of the warm returning brine is registered at the engine room. The temperature in the storage compartments is regulated by the amount of piping used for the flow of brine. As cooler temperatures are required additional piping is opened to permit the flow of a greater volume of brine. A sufficient area of piping is installed so that the storage rooms, with the exception of the freezer rooms on the two upper floors, can be operated with a brine temperature as high as +16 F. This gives a very flexible system and provides for unforeseen emergencies. Four brine pumps are provided for circulating the brine. Under the present operating conditions only one circulating pump has been required to furnish the necessary brine for cooling the compartments. The use of the low temperature brine reduces the

* Purdue University Agricultural Experiment Station.

volume necessary to supply the required amount of refrigeration.

Air Conditioning System Used

The relative humidity of the air in all compartments is accurately controlled by an air conditioning system. By means of this system fresh outside air is passed through a refrigerated coil and chilled to a temperature that will remove the surplus moisture and reduce the relative humidity of the incoming air to the required percentage for the particular room. The fresh air is circulated through the storage room and the vitiated, carbon dioxide-laden air is expelled from the room. By this system the condition of the air may be accurately controlled and the optimum humidity maintained uniformly at all times or varied when necessary to fulfill the requirements of a different type of produce.

Sprinkler Pipes Filled with Brine

Another interesting feature of this building is the fire protection system provided in all of the storage rooms. The ordinary type of overhead sprinkler systems has been installed, but as water would not be dependable under low temperature where freezing might take place, the sprinkler pipes are filled with calcium chloride brine. A sufficient quantity of brine is maintained in the pipes to keep them filled. In event of a fire the nozzles first emit a spray of brine, but this is quickly followed by clear water. In this manner the efficiency of the system is maintained at all times without fear of freezing. This system has reduced insurance rates appreciably.

In the storing of goods in this warehouse careful attention is paid to details that frequently are overlooked, but which add very materially to the manner in which the produce behaves during storage. The use of fresh, properly conditioned air, adequately circulated about the produce assures high class storage conditions and the goods are held in excellent condition. The removal of the used air is an important part of this process and prevents the accumulation of the poisonous and odorous gases given off by the stored produce. The maintenance of optimum humidity conditions prevents shrinkage and loss in weight as well as preserving the quality of the stored produce.

All goods are stripped to permit the maximum circulation of air about the packages. This adds to the cost and work of storing, but it is felt to be necessary to provide the best conditions. One-inch stripping is used with apple boxes and packages of that nature. For barrels stored on their sides, blocks of wood are nailed on the strips to fit the ends of the barrels and hold them firmly in place.

Heating *and* Air Conditioning *the* Carbide *and* Carbon Building

By A. McCawley*

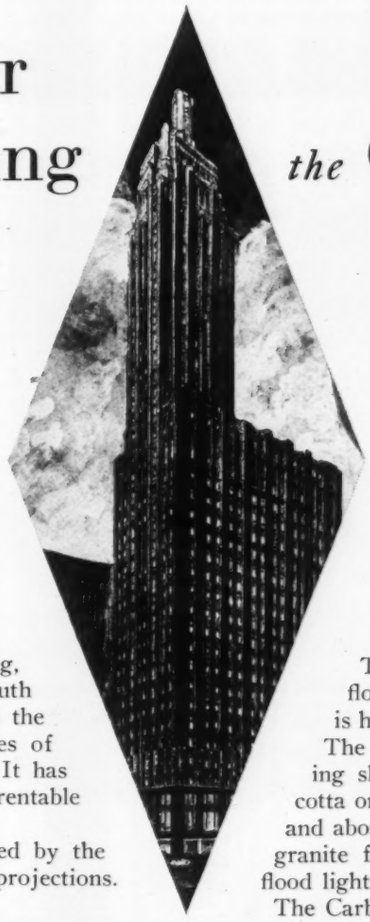


FIG. 1—THE CARBIDE & CARBON BUILDING, CHICAGO. BURNHAM BROS., ARCHITECTS

THE Carbide and Carbon Building, located on Michigan Blvd. at South Water Street in Chicago, houses the general offices and offices of subsidiaries of the Union Carbide and Carbon Corp. It has a ground area of 84x131½ ft., and a rentable floor area of 190,000 sq. ft.

The effect of its height is accentuated by the absence of all horizontal cornices and projections. The tower begins at the twenty-fourth floor, continues to the fortieth story, and is here surmounted by a fifty-foot campanile. The structure is of green terra cotta of varying shades relieved by the use of gold terra cotta on the top of the tower, on the campanile, and above the lower stories where polished black granite forms the building's base. The tower is flood lighted.

The Carbide and Carbon corporation and its sub-

* Thomas J. Douglass & Co.

sidiaries occupy the fourteenth to the twenty-first floors, inclusive, and the thirty-fourth floor in the tower. Boiler and machinery rooms are located in the sub-basement; the basement is a garage. The first floor is laid out for shops and a modern restaurant. The remainder of the available floor area is rentable office space.

Pipes Welded

There are no threads on any pipe 2½ in. in diameter or greater in practically the entire heating system, the joints being welded by the oxy-acetylene method. Special valves and expansion joints were installed having beveled welding necks in place of the customary screwed or flanged ends, providing, to all intents and purposes, a complete jointless network of steel and wrought iron piping.

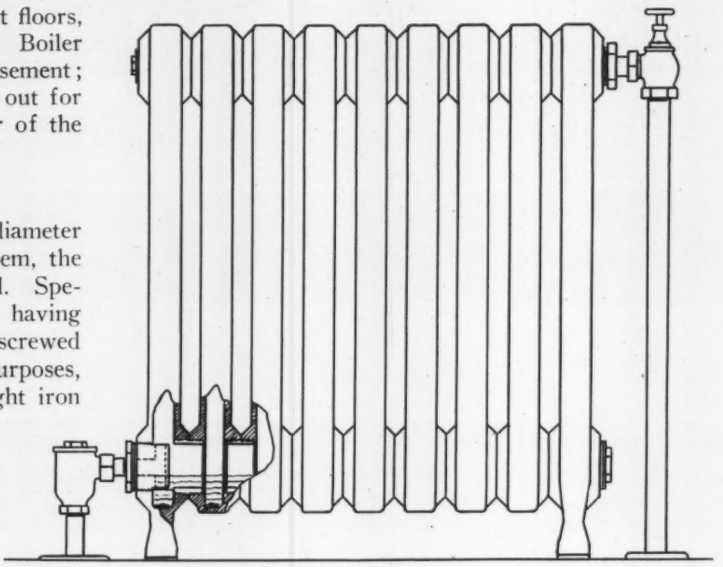


FIG. 2—ARRANGEMENT OF DIRT TRAP BUSHING IN THE VACUUM SYSTEM STEAM RADIATOR

In order to avoid dirty traps, a device of our own design was placed in the return end of each radiator in place of the ordinary bushing, as shown in Fig. 2. Baffles in this dirt trap bushing allow air and condensation to pass freely into the trap, while dirt from the casting,

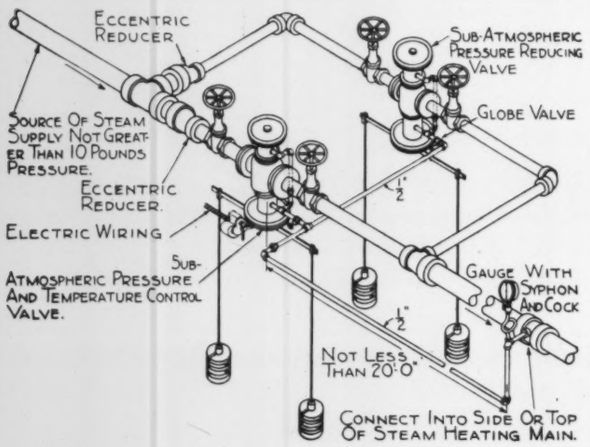

ECCENTRIC REDUCER
SUB-ATMOSPHERIC PRESSURE REDUCING VALVE
GLOBE VALVE
SOURCE OF STEAM SUPPLY NOT GREATER THAN 10 POUNDS PRESSURE.
ECCENTRIC REDUCER.
ELECTRIC WIRING
SUB-ATMOSPHERIC PRESSURE AND TEMPERATURE CONTROL VALVE.
GAUGE WITH SYPHON AND COCK
1½"
1½"
NOT LESS THAN 20'-0"
CONNECT INTO SIDE OR TOP OF STEAM HEATING MAIN.

FIG. 3.—HEAT EMISSION IS VARIED AUTOMATICALLY TO CORRESPOND TO HEAT LOSSES FROM THE BUILDING THROUGH THE USE OF MOTOR-OPERATED VALVES

or any oil or foreign matter coming over with the steam from the supply system of piping, are held in the bottom of the radiator. Where drip traps are installed, a 2-in. cooling leg 4 ft. long is used; the dirt trap bushing installed in the outlet end of this cooling leg, and immediately ahead of the trap, preventing all scum, as well as heavier debris, from the dripped steam main or riser from leaving this chamber. Hence, since each radiator and drip trap is individually protected, trap maintenance is no problem.

The Heating System

A vacuum system supplies steam, usually at subatmospheric pressure, to the direct radiation and at boiler pressure to blast heaters and hot water heaters. The direct radiation load is divided into two zones for fuel economy, zone No. 1 being the tower and zone No. 2 the lower floors. Each zone has its separate main supply riser from the boiler room as well as separate distribution and return main systems. The two distribution mains are located in a pipe space between the twenty-third floor ceiling and twenty-fourth floor level, zone No. 1 (7,500 sq. ft. radiation) being supplied upfeed, and zone No. 2 (30,000 sq. ft. radiation), downfeed. The 3-in. return main for zone No. 1 also is located in this pipe space, and the return main for the lower system is on the sub-basement ceiling.

All individual distribution risers are separately valved, at their point of connection to the distribution mains, with pneumatic valves, the controls for which are brought to a centrally-located switchboard. Each switch is numbered with its respective riser number. The riser locations are identified by framed photostatic copies of floor plans.

Each zone has its own high vacuum pump, with control equipment designed to maintain automatically a pressure differential of 2 in. of mercury between the supply and return systems. This differential does not vary appreciably whether maintained steam pressure is 5 lb. gage or 25 in. of vacuum.

Heat emission per square foot of radiation is varied automatically to correspond to heat losses from the building, through the use of motor-operated valves installed in the steam main to each zone at the point of connection to the boiler header. (See Fig. 3.) A thermostat at

FIG. 4—DETAIL OF PIPING ON THE 23RD FLOOR

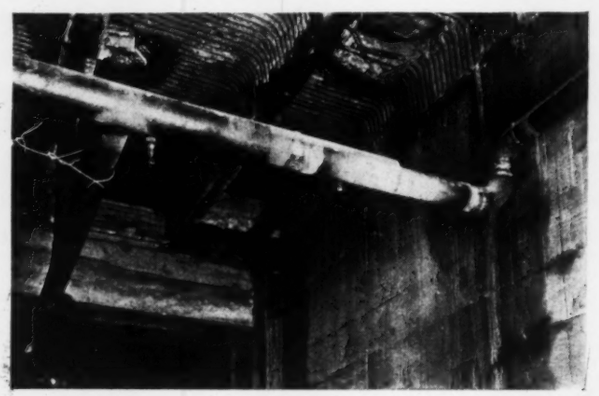


FIG. 5—J. I. BANASH, C. F. KEEL, J. D. HOFFMAN, L. E. OGDEN, AND H. L. WHITTEMORE WATCHING THE WELDING OF PART OF THE WATER PIPING IN THE CARBIDE & CARBON BUILDING

a typical point in each zone actuates its respective motor valve, raising or lowering the pressure in the system for definite temperature requirements according to thermostat setting. Variations in steam pressure cause variations in steam temperature and consequently the heat emission per radiator. The heat emission per square foot of radiation from 100 Btu to 250 Btu or more is changed automatically or manually, thus balancing the heat loss from the building regardless of variation in outside temperature. In mild weather, steam is furnished at 20 to 25 in. vacuum (130 to 160 deg.).

The returns from the blast coils, used for heating the basement and portions of the first floor, as well as the returns from the hot water heaters, have their own vacuum pump.

Steam for the heating system is supplied by two 111 in. diameter by 20 ft. 10 in. long internal furnace type boilers designed for 100 lb. working pressure and of 300 hp. capacity each. Furnaces of the Dutch oven type were installed. In addition to these two boilers there is one 75 hp. down-draft portable boiler for the hot water load. Pop valves on all boilers are set at 10 lb.

Ashes are raised to street level with an hydraulic elevator.

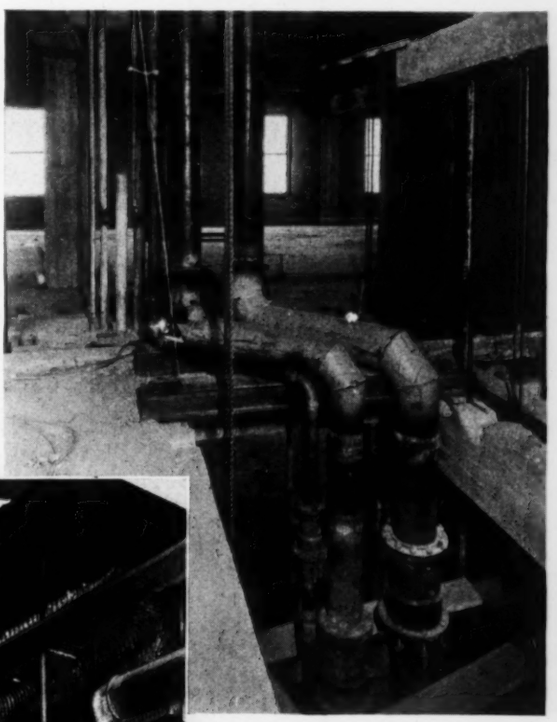
Air Conditioning

The offices of the Carbide and Carbon Corporation are served with conditioned air. A portion of the twenty-fourth floor is devoted to housing the fan equipment, humidifying apparatus, tempering coils and filters. Tempering coils and dampers are thermostatically controlled by air intake temperatures; relative humidity by a humidostat located on the seventeenth floor.

Connecting to the supply riser at each floor is a main duct running the full length of the floor. Branch ducts are taken off this main at intervals of 20 ft., which extend to the outside walls and are below the ceiling line. Metal lath and plaster cover them, giving the appearance of plastered deep beams.

On one side of these ducts, spaced 5 ft. on centers, are copper nozzles of comparatively small area (.27 square inches) equipped with diffusing vanes and capable of adjustment through a considerable vertical angle for air stream direction, with the object that every 100 square feet of floor space may have its outlet nozzle and uniform distribution be secured over the entire ventilated area.

Burnham Brothers, Inc., were the architects and George D. Luce, Jr., the mechanical engineer. Thomas J. Douglass & Company, Chicago, were contractors for the heating and ventilating system.



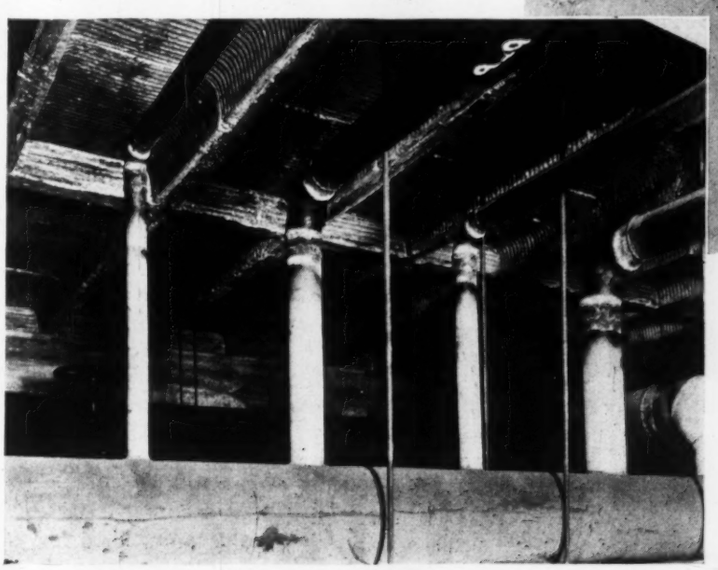


FIG. 6—(LEFT) THE HEADER ABOVE TWO BOILERS

FIG. 7—(ABOVE) OFFSET AT THE FOURTEENTH FLOOR

Factors Affecting the Design of Evaporators

By Herman Vetter*

A REFRIGERATING system may be split up into two main divisions; one is the condensing unit, which includes the compressor, and the other the evaporator unit.

Types of evaporators may be divided into two groups, one of which is called the flash type and the other the flooded type. Evaporators, as used in the refrigerating system, function the same as the steam evaporator (or boiler) and if we analyze it as such we will be able to benefit by the research carried on by boiler manufacturers, which covers a longer period than that of refrigeration research.

Principle of Evaporator

The basic principle of the evaporator is the conversion of a fluid into vapor. To do this effectively, it is necessary to remove the vapor as rapidly as it forms, and prevent any of the fluid from being carried away with the vapor; in other words, we must effectively separate the vapor from the fluid. If this simple principle is followed, little trouble will be experienced in the design of the evaporator.

TABLE 1—PROPERTIES OF THREE FLUIDS

NAME	SYMBOL	TEMPERATURE F	GAGE PRESSURE†
Water	H_2O	32	29.74 in.
Water	H_2O	100	28.00 in.
Water	H_2O	200	6.45 in.
Water	H_2O	212	0.00 in.
Water	H_2O	250	15.12 lb.
Ammonia	NH_3	−28.0	0.0 lb.
Ammonia	NH_3	5.5	20.00 lb.
Ammonia	NH_3	16.6	30.00 lb.
Carbon Dioxide	CO_2	0.0	293.9 lb.
Carbon Dioxide	CO_2	10.0	347.1 lb.
Carbon Dioxide	CO_2	20.0	407.3 lb.

† In inches of vacuum or lb. per sq. in.

The Flash Type

The flash type steam evaporator consists of a series of coils—usually a nest of spiral wound coils. The water is injected into these coils at the bottom and the feed is controlled by the steam pressure, the quantity of water allowed to collect in the coils being kept at a minimum. This permits a variable steam supply without the danger of priming or boiling over. It also permits quick action in starting up, as there is only a small quantity of water to heat.

* Chief engineer, Baker Ice Machine Co., Los Angeles, Calif.

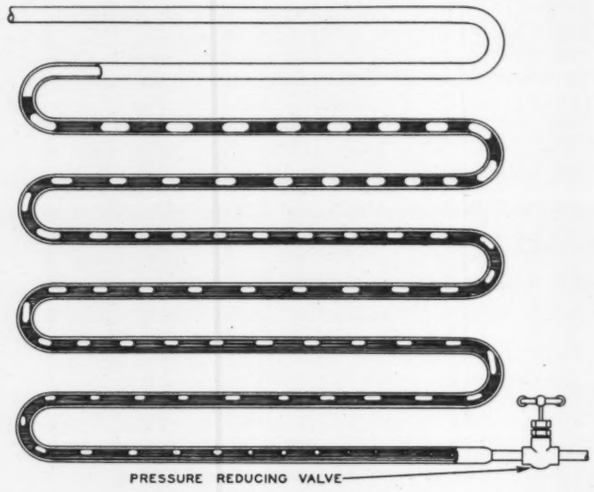


FIG. 1—DIRECT EXPANSION EVAPORATOR WITH LIQUID FEED AT THE BOTTOM

The flash type ammonia evaporator is often termed the direct expansion system and consists of one or more coils connected in series. The question as to the proper place to feed the ammonia has always been a debatable one; the claims advanced by both advocates will be the best way to bring out the various advantages claimed.

Properties of Fluids

In our discussion of evaporators for refrigerating systems, we will consider that we are using ammonia. Basically considered, all refrigerants have the same characteristics, the only difference being in the different operating pressure under which they function. A concise review of the thermodynamic properties of fluids (especially those used for refrigerants) would be advantageous.

All fluids have a given pressure for each evaporating temperature and by referring to Table 1, in which is listed some of the properties of various fluids, it will be easier to follow the operation of the evaporators described.

In this table are listed some of the thermodynamic properties of water as it may be used for refrigerating purposes; it will be shown how the lessons learned in the development of the water evaporator may be used for the development of evaporators for refrigerating systems.

As mentioned previously, all fluids have a given pressure for each evaporating temperature and, by Table 1 it may be noted that water will evaporate at 32 F when the pressure at the water surface has been reduced to 29.74 inches vacuum. At atmospheric pressure, water will evaporate at 212 degrees, while ammonia at atmospheric pressure will evaporate at 28 below zero.

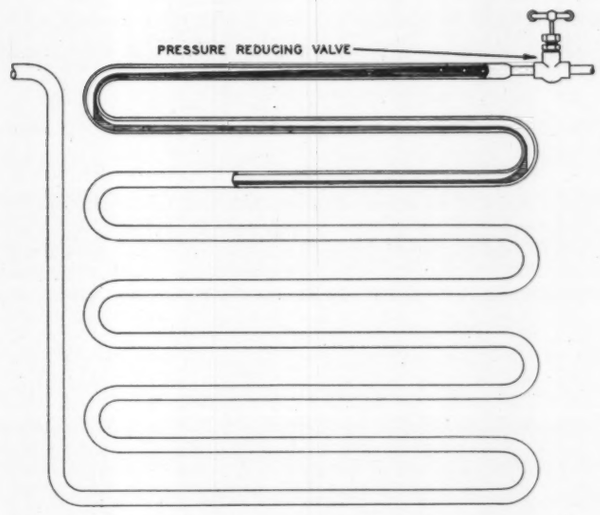


FIG. 2—DIRECT EXPANSION EVAPORATOR WITH LIQUID FEED AT THE TOP

Direct Expansion Evaporator

Refer now to Fig. 1, which illustrates the direct expansion evaporator (flash type) with the liquid feed at the bottom. The refrigerant is fed through a regulating valve which allows the pressure to be reduced from the condensing pressure to the evaporating pressure. The refrigerant, after passing this valve, is subject to a pressure whose corresponding temperature is lower than the air temperature surrounding these coils, consequently the refrigerant begins evaporating and causes the refrigerant to absorb the heat from the surrounding air. The first or lowest pipe of the evaporator will be filled mostly with liquid and with a small quantity of vapor. The proportion of liquid and vapor will change from pipe to pipe until at the top pipe there will be very little liquid and a large proportion of vapor. The function of the ammonia compressor is to take away this vapor so that a constant evaporating pressure can be maintained.

The main difficulty in operating coils of this type is due to the fact that the vapor is passing through the liquid in the coils and forces part of this liquid into the gas main and to the compressor. To prevent this trouble it becomes necessary to operate with a lower liquid level in these coils, which consequently reduces their efficiency. It is difficult to operate this type of coil successfully when operating under a greatly fluctuating load.

The reason the flash type *steam* evaporator can be successfully operated with bottom feed is due to the fact that the temperature difference between the water and the fire is much greater than in the refrigerator evaporator. In the refrigerator evaporator, the temperature difference is rarely greater than 40 degrees, whereas the temperature difference in the steam evaporator is rarely less than 700 degrees; therefore very little water can collect in the coils with this great temperature difference.

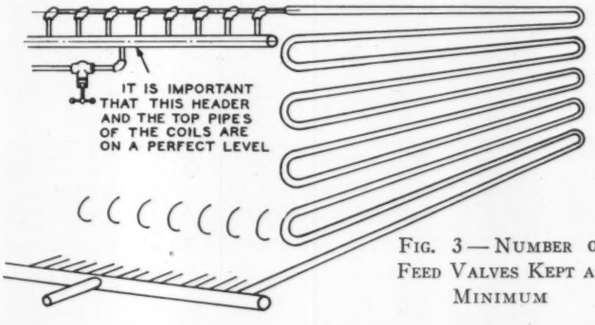


FIG. 3—NUMBER OF FEED VALVES KEPT AT MINIMUM

Direct Expansion Evaporator with Liquid Feed at Top

Fig. 2 illustrates the direct expansion evaporator (flash type) with the liquid feed at the top. The liquid entering the top pipe flows by gravity down through the coil and the gas is carried away from the liquid instead of through it, as is the case when the liquid is fed at the bottom. The supply of liquid with this type of coil may be controlled easily as the flow of the refrigerant is steady because the vapor is not forced through the liquid. This type of coil is easily defrosted and long coils are possible for each control valve. When defrosting this type of coil, the water and ice which has been released from the upper pipes does not freeze onto the lower pipes because no liquid has been trapped in these pipes.

For large evaporators of the flash type, the number of feed control valves can be kept at a minimum by an arrangement similar to that shown in Fig. 3. For determining the length of run per coil, the writer believes the velocity of gas leaving the coil should be kept under 1,000 feet per minute to obtain the best results. The writer has installed 2,500 feet of 2-in. coils under one feed operating with a temperature difference of 12 degrees. Under these conditions the estimated gas velocity leaving the coil is 876 feet per minute.

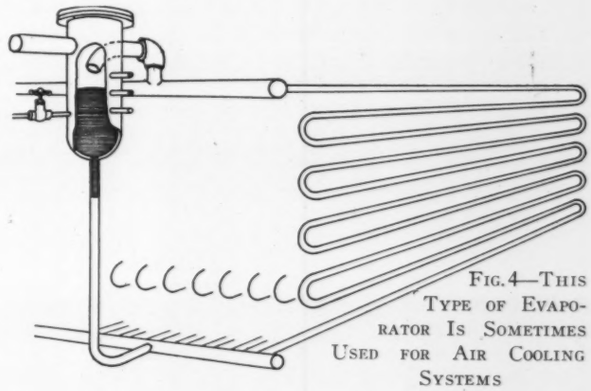


FIG. 4—THIS TYPE OF EVAPORATOR IS SOMETIMES USED FOR AIR COOLING SYSTEMS

Flooded Type Evaporators

In Fig. 4 is illustrated a type of evaporator which has been popular for many years. This design was the outcome of experiments made by Professor R. L. Shipman of Cornell University, New York. It is used for brine tanks and ice making tanks and, in some cases, for air cooling purposes.

The liquid is usually fed directly into the accumulator although, in some cases, it is fed into the liquid header. In the original experiments made by Professor Shipman, he fed the liquid into the line between the top header of the coil and the accumulator. In later experiments he tried various points to feed the liquid with apparently no difference in the results.

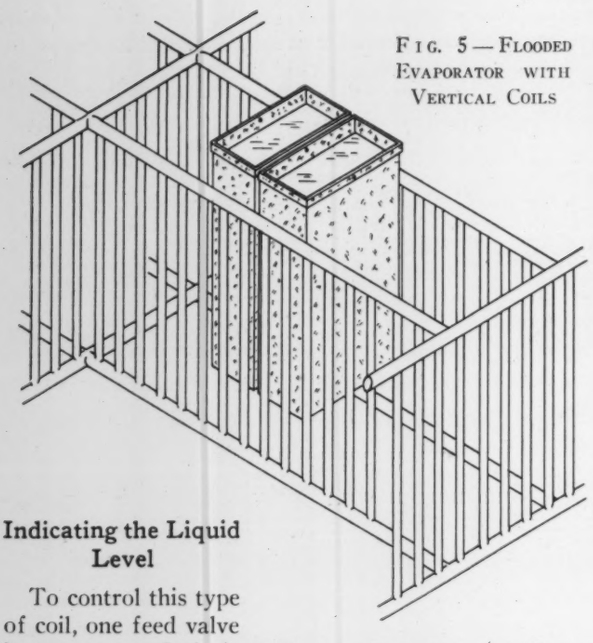


FIG. 5 — FLOODED EVAPORATOR WITH VERTICAL COILS

Indicating the Liquid Level

To control this type of coil, one feed valve is necessary. It is important to have some method to gage the height of the liquid necessary to keep the coil fully flooded. The ordinary water level gage, as used on a steam boiler, is not practical as the glass will frost and the liquid level in the glass would be abnormal due to the ebullition caused by the boiling liquid. For the purpose of indicating the liquid level, Professor Shipman devised a tell-tale made by welding in pipe stubs as shown in Fig. 4. These stubs should be long enough to project beyond the insulation of the accumulator at least one-half of an inch. There has been put on the market a gage glass placed within a vacuum tube which indicates the liquid level at all times and allows the normal liquid level to be easily maintained.

There were many modifications of the type of coil shown in Fig. 4. Many engineers, however, overlooked the basic principles and made the lengths of the coils too long, which caused an accumulation of vapor in them, reducing the wetted surface with a consequent reduction in heat-absorbing capacity. It was not uncommon for ice-making tank coils to be made seventy feet long and ten pipes high of 1¼-in. pipe, which resulted in more than a 1,300-foot per minute gas velocity leaving the coil.

One change made in flooded type evaporators was brought about not with the idea of improving its efficiency, but to reduce the possibility of damage to the coils in the event that an ice can should slip from the hoist and fall on the coils. To offset this possibility, the pipes in the coil were placed vertically as shown in Fig. 5.

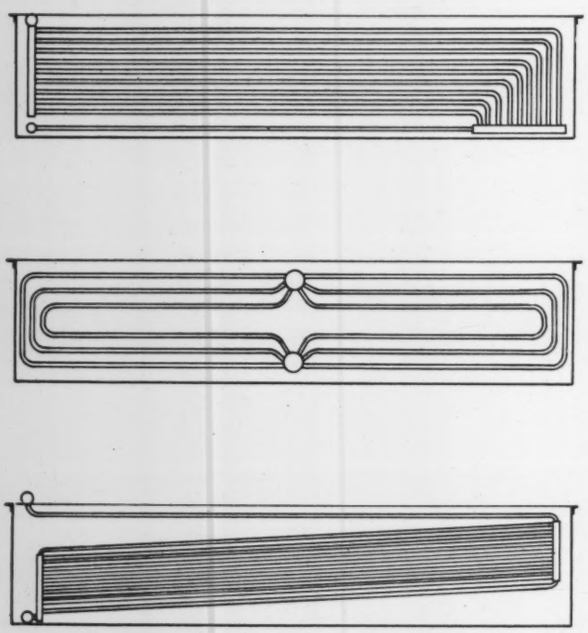


FIG. 6—MODIFICATIONS OF THE COIL SHOWN IN FIG. 5

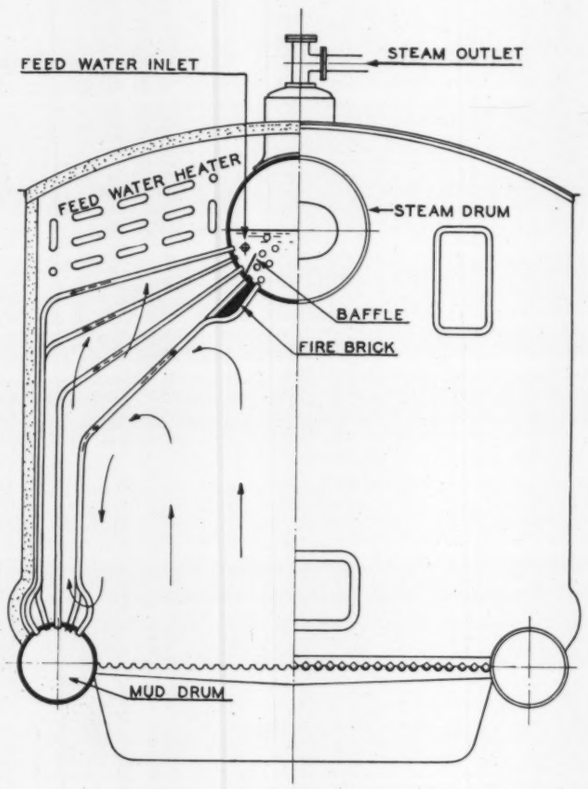


FIG. 7—ILLUSTRATING THE PRINCIPLES OF BOILER DESIGN APPLIED TO EVAPORATORS

Vertical Tubes

In a vertical tube the gas does not cling to the evaporating surface readily; consequently practically all of the surface is effective in absorbing heat. Here again was sufficient evidence that had the refrigerating engineers realized that their problems were no different than that confronting the steam engineers, they would have investigated the reason steam engineers got such good results from water tube boilers. Had they done so, they would have developed the present type of evaporator many years sooner.

Fig. 7 shows one type of water tube boiler in which is indicated the flow of heat and the water circulation caused by directing the heat flow. The most intense heat comes in contact with the first two rows of tubes, which are nested close together to form a baffle, causing the heat to flow counter to the water in the first two rows of tubes. In the outer tubes, the water flow is

downward to replace the water rising up through the inner rows of tubes. The feed water is fed into the steam drum near the outer row of tubes. The principle underlying the design of the water tube boiler is no different than that in the design of the present types of flooded type evaporators. There is no reason why a steam boiler could not be used for a refrigerator evaporator provided the heat flow were directed in the same manner as is necessary for steam purposes.

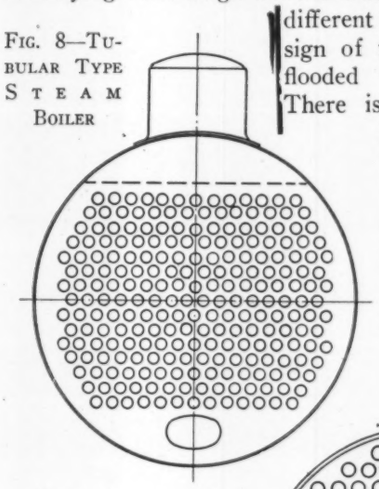


FIG. 8—TUBULAR TYPE STEAM BOILER

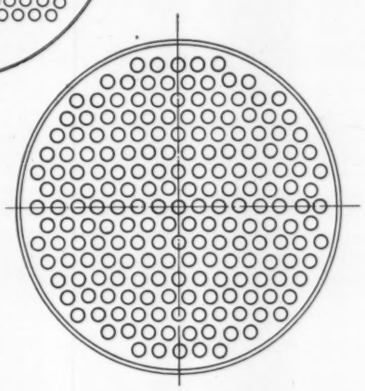
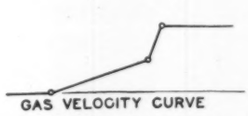


FIG. 9 — (RIGHT) SHELL AND TUBE BRINE COOLER

Shell and Tube Cooler

The shell and tube brine cooler is very similar to the tubular type boiler. In Fig. 8 is shown a typical tubular type steam boiler and in Fig. 9 a conventional type of shell and tube brine cooler. You will note that the steam engineer provides space above the tubes for the steam to collect, whereas the refrigerating engineer sometimes crowds as many tubes into the shell as is possible and makes no provision for collecting the vapor. This is even more astonishing when we realize that when the shell and tube brine cooler was developed, most manufacturers were also making boilers. In order to overcome this difficulty Fig. 10 suggests a remedy for this difficulty without losing tube surface.

In this arrangement, the writer suggests providing the cooler with two gas outlets and connecting these outlets with a yoke. This arrangement would give a gas velocity increasing from zero until it reached the velocity in the main suction line, which is often as high as 2400 feet per minute. Such high gas velocities are usually not desirable because low velocities give a higher volumetric efficiency for the compressor than do high gas velocities. Any design of gas outlet on the brine cooler that will give a steadily increasing velocity from the cooler to the suction main is to be recommended. Placing a dome on top of the cooler similar to the dome on the steam boiler would give very good results. The arrangement shown in Fig. No. 11 is a very popular arrangement, but in it the velocity curve rises from zero to maximum and then drops near the zero line only to rise again to the suction line velocity.



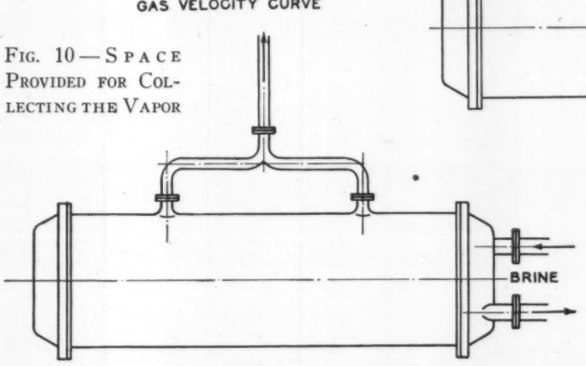


FIG. 10 — SPACE PROVIDED FOR COLLECTING THE VAPOR

FIG. 11—(RIGHT) AN ARRANGEMENT USED FREQUENTLY

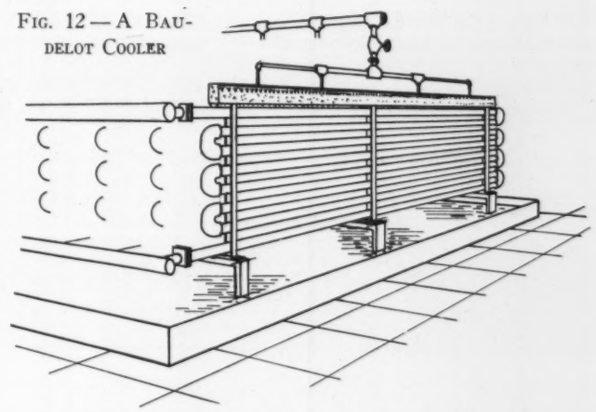


FIG. 12 — A BAUDELOT COOLER

Baudelot Cooler

The baudelot cooler is illustrated in Fig. 12. With this type of evaporator, the water or brine which is to be cooled is fed into troughs located directly above the coils and is allowed to trickle down over the pipes, being collected in a catch basin below. The refrigerant is fed into the bottom pipe so that there is a counter-flow between it and the liquid to be cooled. A method commonly used for controlling the refrigerant is the same as that shown in Fig. 4; the method shown in Fig. 3 could be used.

Surface Required

In Table 2 are listed the heat transfer coefficients used by many manufacturers. The coefficients listed in this table are used in the following formula to determine the evaporating surface required.

$$\frac{\text{Btu/Hour}}{\text{Coef. x } T.D.} = \text{Sq. Ft. Surface}$$

The coefficient multiplied by *T.D.* (temperature difference between the outside and inside of the evaporating surface) divided into the quantity of heat to be removed per hour expressed in British thermal units gives the square feet of evaporating surface required.

TABLE 2—TYPICAL HEAT TRANSFER COEFFICIENTS

TYPE OF EVAPORATOR	HEAT TRANSFERRED		COEFFICIENT
	FROM	TO	BTU HEAT TRANSFER PER SQ. FT. PER DEG.
Direct Expansion (Fig. 1)	Air	Refrigerant	2.5
Direct Expansion (Fig. 2)	Air	Refrigerant	2.5
Flooded Type	Brine	Refrigerant	15.0
Radiator Type	Brine	Refrigerant	70.0
Boiler Type	Brine	Refrigerant	70.0
Shell and Tube Cooler	Brine	Refrigerant	75.0
Baudelot Cooler	Water	Refrigerant	80.0

3. Percentage of evaporator surface wetted by the refrigerant
4. Circulation or velocity of the element to be cooled

Item No. 1 is governed by the material used for the evaporator walls.

Item No. 2 can be kept at a minimum by providing sufficient evaporator surface to allow the evaporator to operate with minimum temperature difference between the refrigerant inside the evaporator and the air in contact with the evaporator surface.

Item No. 3 is very important, as the effectiveness of any refrigerant depends on the latent heat of evaporation. The evaporator surface in contact only with the vapor will absorb very little heat. To keep the surface wetted, it is very necessary to get rid of the vapor as soon as possible, and to provide a steady supply of liquid refrigerant to replace the evaporated refrigerant.

Item No. 4 is important, as there must be a steady flow of the brine or water in contact with the evaporator surface.

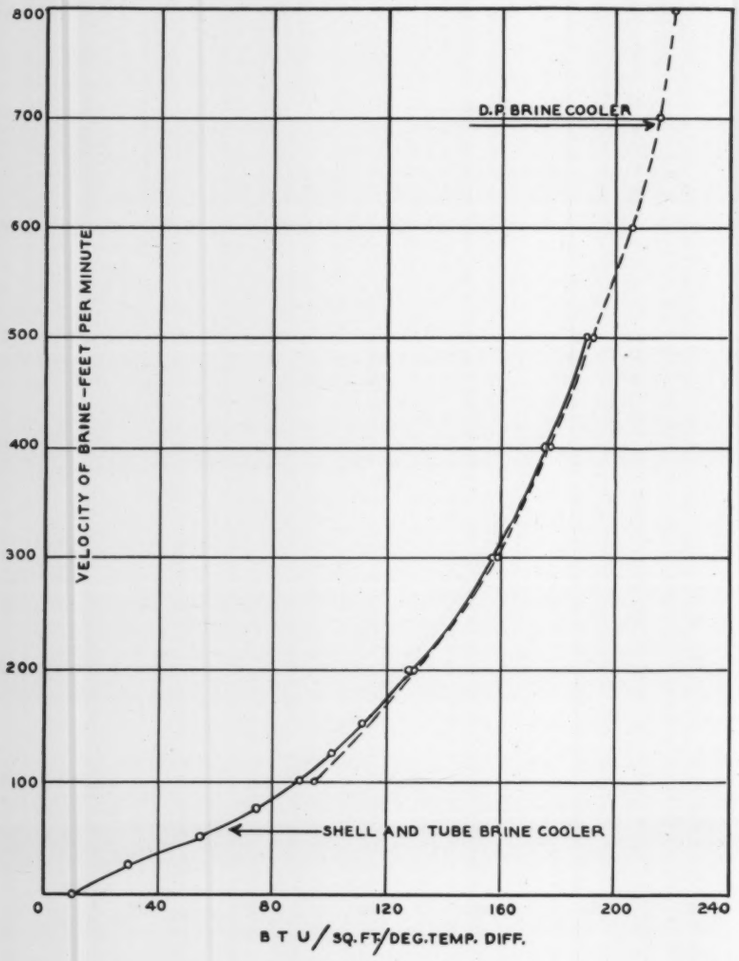


FIG. 13—CURVE PLOTTED FROM TESTS SHOWING THE INFLUENCE OF THE BRINE VELOCITY ON THE COEFFICIENT IN THE FORMULA FOR SQUARE FEET OF EVAPORATING SURFACE

For cooling a liquid such as brine, the temperature difference can be kept as low as two degrees. For air cooling, the temperature difference may range from 10 to 40 degrees depending upon the air condition desired. Whenever possible, the temperature difference should be kept at a minimum as that allows the compressors to operate at a higher evaporator pressure with consequent less compressor brake horsepower. The coefficient therefore is the only variable factor which we should strive to increase in our evaporator design.

Factors Affecting Design

The following factors govern the coefficient:

1. Thermal resistance of metal (tube walls)
2. Frost accumulation

Influence of Brine Velocity on Coefficient

A coefficient curve obtained by tests is plotted in Fig. 13; this shows the influence of brine velocity on the coefficient. The factor determining the limit of velocity is the horsepower required to obtain this velocity.

Heating·Piping
and Air Conditioning

American Society of Heating and Ventilating Engineers JOURNAL SECTION

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Progress in Heating and Ventilating During the Past Quarter of a Century

By Reginald Pelham Bolton[1], New York
MEMBER

TWENTY-FIVE YEARS have passed since the tenth anniversary of the formation of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS. On that occasion our valued member, Prof. Rolla C. Carpenter, presented an interesting, though brief, review of the art of heating and ventilation as it had existed and developed during the period of fifty years prior to that commemoration.

Now that art has made its way along the path of modern progress during another quarter of a century, and it may be well to regard the present year as another milestone, from which we may look back and take note how far we have traveled, and over what obstacles we have made our way.

Such retrospective consideration has a practical value if it induces us to reflect upon our own limitations, and also to compare our present advantages of accumulated knowledge and available materials with the limitations and difficulties through which our predecessors struggled to achieve success.

We may reflect without undue pride that in the processes of heating and ventilation, we are dealing with a matter which more directly than any other branch of the mechanical sciences conduces to the necessities of mankind. Man could eke out his life without many modern devices and conveniences, but he is and will always remain dependent for his very existence upon respiration, temperature, and humidity.

Contribution to Disease Reduction

With the reliable and adequate provision of warmth and pure air, our branch of science has made no small contribution to the reduction of disease, and to the prolongation of human life, during the past quarter of a century. We may congratulate ourselves that we, the heating and ventilating engineering profession, have contributed to this desirable end. But we must modestly admit that we have been aided in our progress by the improvement of appliances and materials, and the increase in scientific information which has accompanied the rapid march of modern developments.

We have, moreover, to credit our predecessors with the initiation of methods and the achievement of results, by which we have benefitted, methods adopted and achievements accomplished by them with a restricted supply of dependable information, and without the experience and the means and materials which we now find so readily available.

At the tenth annual meeting of the Society in 1904, Hugh J. Barron had presented a review of existing literature bearing upon the subject of heating, which was chiefly in the form of papers that had been communicated during the prior decade to the *National Association of Master Steam and Hot Water Fitters,* and to the *Heating and Ventilating Institution of Great Britain.* These were supplemented and enlarged by the topical discussion and some valuable papers contributed by the membership of our own Society. These presentations had, by 1905, gradually built up an accumulation of records of the experiences of individual theorists, scientists and engineers.

Reference Books in Use

But apart from these rather discursive items of information there was a lack of standardized literature and of factual record. The most dependable book of reference was that admirable work by the lamented Carpenter, Heating and Ventilating Buildings,[2] supplementing William J. Baldwin's highly successful book, Steam Heating for Buildings[3], which was published in 1881 and had run at that time through fourteen editions. And a much-needed contribution upon the subject of ventilation in school buildings appeared in 1905, written by Joseph A. Moore, Inspector of the Public School System in the State of Massachusetts.[4]

Our problems of the first years of this century were largely attributable to the absence of many of those improved appliances, and materials which have since been rendered available. We were still wrestling with the question of pipe sizes, to which James A. Donnelly had begun his contributions of experiment and original study. Some work had been done in determining the transmission of heat through various building materials.

The effect of wind upon building surfaces, and the extent of inward leakage into buildings were occupying attention. Our problems were intensified by the development of tall buildings in great cities, constantly increasing in height. Compulsory ventilation in school buildings had made an advance by the action of the Legislature of the State of New York, in passing the bill requiring adequate ventilation of schools, the culmination of many years of effort.

Typical Problem of 25 Years Ago

I may venture to illustrate the circumstances of the work of planning the heating of buildings twenty-five years ago by my own experience at that time. In the year 1905, I found myself confronted with problems of a somewhat unusual character in the preparation of the

[1] President, R. P. Bolton Company.

For presentation at the 37th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Pittsburgh, Pa., January, 1931.

[2] Heating and Ventilating Buildings, a manual for heating engineers and architects, New York, 1895.

[3] Steam Heating for Buildings, or Hints to Steam Fitters, N. Y., 1881.

[4] The School—Its Heating and Ventilation, Boston, 1905.

preliminary plans and computations of the heating system to be applied to the Grand Central Terminal in New York City. This was a group of prospective buildings of unusual character, spread over a large area and of possible increases in size which at that time were mere matters of conjecture. The system to be devised, therefore, required consideration of future extensive developments and the provision of steam supply capable of very considerable future expansion. There being no available body of recorded proportions it was necessary to compute the probable heating requirements of every element in the project as an individual problem.

It is of interest to record that the final decision in regard to the nature of the heating system was in favor of the use of a forced circulation of hot water rather than the distribution of steam. An unusual feature in the entire group of buildings was the provision of working space upon an upper floor of each structure, as there was no basement in these buildings, the space being occupied by the railroad tracks. The lower floors of these buildings are hung from girders extending through this working space, through which the main piping of the heating system had to be arranged and return piping had to be planned through the lower story and some part of the public terminal spaces. Radiating and piping proportions had to be decided largely by the exercise of judgment rather than by recorded experience. I am glad to be able to record that this extremely interesting problem was successfully solved.

Then came a question which had up to that time attracted little consideration, namely the current expense of operation of this extensive installation. The design of a steam-producing plant was then developed and it is interesting to note that this plant, situated on Fifty-first street, continued in service for a period of twenty-five years, having been quite recently dismantled to make way for the Waldorf-Astoria Hotel, the steam for the plant being now supplied by the underground system of the New York Steam Company. This problem involved a study of recorded weather conditions over a long period, and consideration of average temperatures, and average use of heat.

One of the developments in the planning of heating plants, derived from actual tests of heating systems grew out of these studies. The prolonged and detailed test of the heating and power plant in the Hall of Records in New York City afforded much information on the variations and the total quantity of steam which was required in modern buildings, accompanying the variations of exterior temperature and wind movement. Later tests have established a firm relation between the cubical contents of a building and the usage of steam in heating it.

Comparisons of the actual amount of steam used from hour to hour in cold weather has thrown a great deal of light upon the economic side of the subject. It has been followed in recent years by studies of the comparative use of steam and of hot water as a medium for the transfer of heat, and also of the relative advantages of maintaining a fixed interior temperature during the night time in unoccupied buildings, or of the discontinuance of the heating process during that period. As a result of these investigations and determinations the cost of the heating of buildings has gradually become defined and should now no longer be a matter of mere estimate.

Development of Appliances

During the period covered by this review it has been noticeable that the manufacture of appliances used in the work of heating have developed many improvements in heating apparatus and in greater variety, which has greatly aided in the design and operation of modern heating plants. Electrically operated blowers and fans have become available in all sizes and types. A notable improvement, which was introduced in 1906, was the *squirrel cage* type of blower, which has since that time demonstrated its efficiency and has become a substantial aid in the work of ventilation.

Attention has been directed and most important developments have followed upon the question of the purity of the air dealt with by systems of ventilation. The purification of air introduced into buildings may be rightly considered the greatest advance which has been made in ventilation during the past quarter of century.

What we now rather clumsily describe as the process of *air conditioning* is largely due to the lifework of our esteemed Vice-president, W. H. Carrier. It has had the effect of lifting the subject of ventilation from a mere mechanical system to a scientific and hygienic process. Its importance has been upon an increasing scale, since the contamination of air in great centers of population has proceeded on an increasing scale.

Some attention has been directed towards the reduction of dust contained in the atmosphere, but not much has been accomplished in this direction. Public attention and scientific observation have been mainly diverted towards the limitation of visible smoke, ignoring the dangers and discomforts arising from the accompanying volume of fine ash which is discharged by all power plants and by the chimneys of heating apparatus.

Recently developed devices for catching dust or ash present a promise of effective dealing with this problem. The reduction of contamination of the atmosphere should be corrected at its source. These considerations, however, do not detract from the desirability of the purification of air introduced into buildings.

Air Conditioning

Directly connected with the process are the developments in method of cooling the interior atmosphere, in which direction some installations have been successfully operated. Some of our members will recall with satisfaction their experience of the cooled spaces in the Blackstone and LaSalle hotels upon the occasion of our Society's annual summer meeting in Chicago during the scorching heat of 1912.

Perhaps more than any other phase of this important development of the art of ventilation is the relative humidity upon which so much of the comfort as well as the health of human beings depend. As a part of the system of air conditioning, it has great hygienic importance and places the subject of proper ventilation upon a high scientific level. Installations of this character are now to be found in successful operation in places of amusement and hotels, their use, however, being restricted largely to the summer months. It has yet to be understood by the public that health is as much to

be conserved, and that respiration requires as much safeguarding in closed buildings in winter, as in summer.

During the period covered by this review the use of oil-burning apparatus has advanced, with particularly rapid developments during the past few years. This source of heat production has had important effects upon the interior heating of buildings, by reason of its convenience and its ready adaptation to automatic control. Its use in domestic heating is destined to expand, due to these features and to the ceaseless activity of producers of oil, as well as the intelligent advocacy of the various forms of burners and of automatic control devices which are now on the market.

Gas, Oil and Electricity

The use of gas as a fuel for heating purposes has not advanced as rapidly as has the use of oil, due to the fact that the one is a raw or nearly raw product, and the other a refined and therefore more costly form of fuel, but this situation is destined to change as the extension of a supply of natural gas proceeds, which has taken definite form within the past few years. Nevertheless the consumption of artificially-produced gas even at metropolitan prices, may prove advantageous and economical in view of the simplicity and security of its supply and its utilization. It may not be inappropriate to state that the writer has used artificially produced gas at the prices established in New York City, for the past seven heating seasons in a business and apartment building, in which the expense of this fuel though more than double that of coal, has been economically justified by the circumstances under which it is consumed. These include the elimination of labor, the absence of ashes and of the handling of fuel, which has made it possible to utilize a valuable basement space for storage and workshop purposes, and finally, the great convenience of automatic control.

Some advances have been made in the production and in the use of electrically-operated heaters, which in spite of the cost of an expensively-refined form of energy, have been found in many places economically advantageous as auxiliary heating apparatus.

Establishment of Research Laboratory

Perhaps the most important and promising advance in the knowledge of the fundamental facts relating to heating and ventilation has been the establishment of systematic research which began to take form in 1917, when the subject was taken under consideration by our Society. In 1918 a committee was appointed to formulate a plan and method of prosecuting this important project, and at the twenty-fifth annual meeting of the Society, the work of research was authorized and started.

The results which have already been attained indicate the great importance of this line of study and investigation. Progress has already been made in standardizing the conditions of the processes of heating and ventilation. The determination of efficiency of various appliances has already laid the foundation for the future development of the art of heating and ventilation upon defined systems by the use of ascertained methods and reliable apparatus.

The work of the Society and of heating engineers in general has thus advanced along lines increasingly directed by accumulated experience, test, and information during the past twenty-five years, largely as a result of the labor of our interested members.

Finally, looking over the quarter of a century through which we have passed, it is evident that the arts of heating and ventilation have traveled far. But we may learn from our brief consideration of that progress, the conclusion that there lies before us a great field of endeavor and accomplishment. Devoted to the progress of the human race and realizing how much contribution we may make to the health and happiness of our fellow-creatures, we may well gather inspiration from the progress of the past quarter century, and with confidence move forward to greater achievements.

Carbon Monoxide Hazards, Especially Prevalent at this Season, Visualized in Motion Picture Film

The arrival of the season when the death toll due to carbon monoxide mounts rapidly leads the United States Bureau of Mines, Department of Commerce, to call attention to the availability for exhibition purposes of its one-reel motion picture film entitled Carbon Monoxide: The Unseen Danger, which visualizes the hazards of this insidious poison gas and points out ways of combatting these dangers. Despite the many warnings sounded, hundreds of people are killed yearly from exposure to carbon monoxide, present in automobile exhaust gases, manufactured gas, and in other gases. The Bureau of Mines film has been prepared, in co-operation with an automobile manufacturing company, for the express purpose of helping to reduce the heavy annual death rate from this cause.

The early scenes of the film depict the extreme danger of running an automobile engine in a closed garage. As a man is starting the family car within the garage, the doors blow closed and, while the engine is being warmed up, the carbon monoxide fumes in the exhaust gases overcome the unsuspecting driver. The family, waiting for the car, become uneasy over the delay, and the son, a boy scout, is sent to investigate. The boy, finding his father prostrate, applies his boy scout training by dragging his father to the open air and immediately starting artificial respiration. A doctor is summoned and the local fire department rushes to the scene with an oxygen inhalator. By the application of these prompt measures, the man's life is saved. Other instances of exposure to carbon monoxide fumes in closed garages in which the victim is not so fortunate are, however shown. "Never run the engine in a closed garage!" and "Keep the doors open!" are the warnings thrown upon the screen.

The hazards from carbon monoxide likely to be encountered in repair shops and service stations are depicted in other scenes. A heedless mechanic, starting to get beneath a car while the engine is running, is jerked back to safety with the admonition "Never get under the car while the engine runs!" Headaches and half-sick conditions are often due to the presence of carbon monoxide in garages and service stations, the film points out. Methods of proper ventilation of such places are shown.

Spectral Distribution of the Energy Radiated from Metallic Surfaces at High Temperatures

By G. R. Greenslade[1], Pittsburgh, Pa.
NON-MEMBER

This paper contains information of scientific value on the subject of radiation from metallic surfaces. While the data are not directly applicable to the problems of the heating and ventilating engineer, they are of considerable value in connection with certain phases of heat emission by direct radiation. It is contemplated that this paper will form the basis for additional work at the A.S.H.V.E. Laboratory on other metallic surfaces in which the heating engineer is interested.

THE WORK of determining the exact nature of the thermal radiation from the polished surfaces of metals was begun by Paschen[2] who in 1896 published the results of an investigation which seemed to indicate that the spectral distribution of the heat radiation from certain metallic surfaces at temperature T degrees Kelvin (centigrade absolute scale) could be expressed by the following equation:

$$E_{\lambda T} = C_1 \times \lambda^{-a} \times e^{-C_2/\lambda T} \qquad (1)$$

where

λ = the wavelength of the radiant energy E

C_1, C_2, a = constants depending upon the nature of the metal under consideration.

In 1899, Lummer and Pringsheim[3] experimentally obtained a number of spectral energy distribution curves for platinum covering a fairly wide range of temperatures. On attempting to check Paschen's equation by means of these data using $a = 6$ they found that the theoretical curves dropped off more rapidly at both extremes than did the experimental ones, thus indicating that the equation was inadequate for use over more than a very narrow range of wavelengths. Subsequent to this Aschkinass[4], by means of Planck's[5] black body radiation law, Kirchoff's law, and the relation which Maxwell's electromagnetic theory indicates should exist between electrical resistance and reflecting power, derived the following equation which it was thought might be applied to all metals:

$$E_{\lambda T} = C_1 \times 0.0221 \sqrt{\rho_0 T}\ \lambda^{-5.5} \times \frac{1}{e^{C_2/\lambda T} - 1} \qquad (2)$$

The symbols used are the same as those previously used with the exception of the new quantity ρ_0, which represents the specific resistance of the specimen at zero degrees centigrade.

This equation agreed with the experimental curves for platinum obtained by Lummer and Pringsheim much better than did equation (1), and accordingly it was incorporated in an article by O. Lummer[6] and republished, together with the curves, showing the experimental agreement. There are, however, two points in the derivation which make the extensive applicability of the equation questionable. The first of these is that it is based on the Maxwell relation mentioned, i. e.

$$100 - R_\lambda = \frac{36.5}{\sqrt{\lambda}} \times \sqrt{\rho} \qquad (3)$$

where

R_λ = reflecting power of the metal for radiation of wavelength λ

ρ = its specific resistance.

This theoretical equation was found by Hagen and Rubens[7] to hold only for very long wavelengths of the order of 12μ or greater, while for wavelengths of 4μ their work showed that in the determination of the values of the quantity,

$$C_\lambda = \frac{100 - R_\lambda}{\sqrt{\rho}} \qquad (4)$$

for the various metals and alloys used there was an average deviation from the mean of 21 per cent. The second questionable step referred to is that the introduction of ρ_0 in the equation, involved the assumption of complete linearity for the temperature function of resistance.

A number of years after the publication of the investigations of Lummer and Pringsheim, G. V. McCauley[8] repeated essentially the same work that they had done on platinum using apparatus so constructed that the beam of radiant energy passed through practically no absorbing medium from the time of its emission by the metallic surface up to the time of its absorption by the bolometer which measured its intensity. This was a distinct improvement over any method which had been used before and gave results which were more nearly free from absorption bands. McCauley also obtained comprehensive sets of curves for both palladium and tungsten.

[1] Chief Physicist, Flannery Bolt Company, Pittsburgh, Pa.

[2] Wiedemann; *Annalen der Physik und Chemie*, 58-455-1896; 60-662-1897.

[3] *Verhandlungen der Deutschen Physikalischen Gesellschaft*, 1-215-1899.

[4] *Annalen der Physik*, 17-960-1905.

[5] *Vorlesungen uber die Theorie der Warmestrahlung*, Leipzig, 1906.

For presentation at the 37th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Pittsburgh, Pa., January, 1931.

[6] *Handbuch der Elektrizitat und des Magnestismus*, Band 2, Lief, 2-462-1914.

[7] *Annalen der Physik*, 11-873-1903.

[8] *Astrophysical Journal*, 37-164-1913.

The purpose of carrying on the experimentation described in this paper was to extend the data in this field so as to include analyses of the radiation spectra of a number of metals not previously investigated, in order that further tests might be made of the applicability of some of the theoretical distribution equations which have been evolved. The form of apparatus and the methods employed in the present work were somewhat similar to those used by McCauley, though they have been modified in many details so as to eliminate certain difficulties which he encountered. A number of curves were obtained for each of the following metals: Tungsten, iron, molybdenum, nickel, cobalt, iridium, rhodium and gold, and in addition to this, the work on platinum was repeated for comparison purposes.

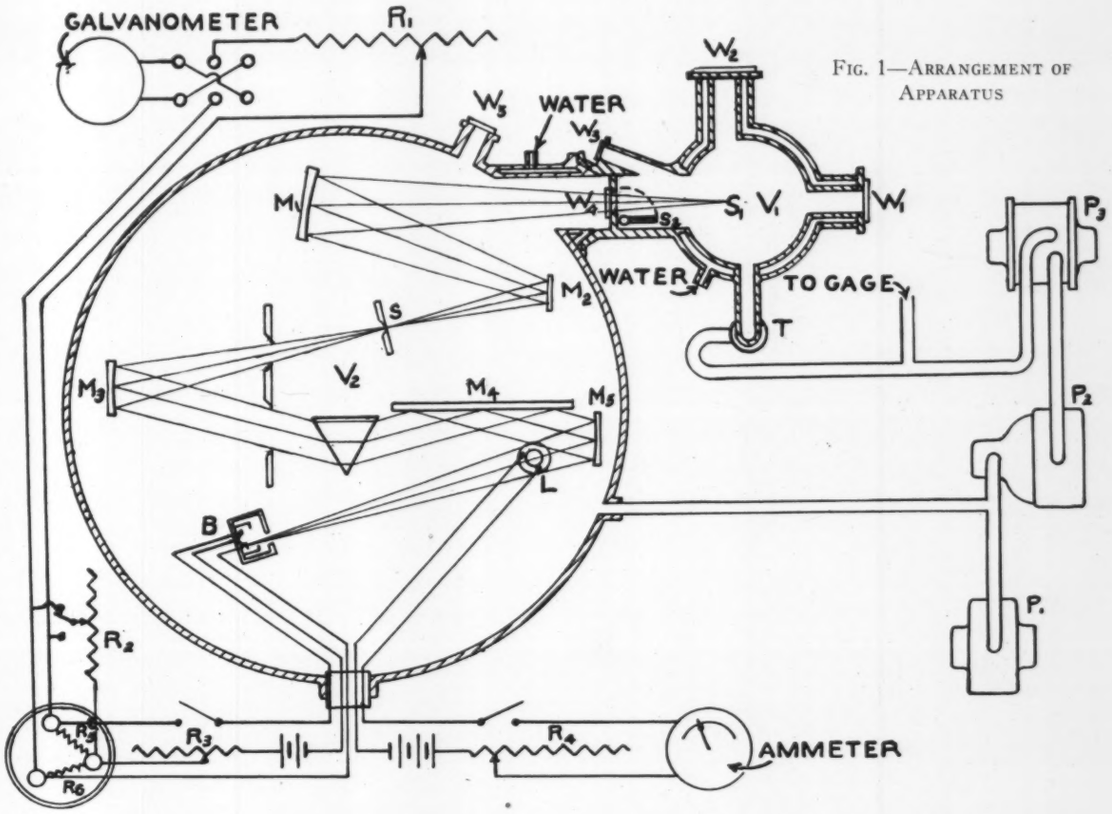

FIG. 1—ARRANGEMENT OF APPARATUS

Apparatus

The general arrangement of the apparatus as used in this analysis is shown in Fig. 1. The specimen to be tested was placed at S_1 in the water cooled vacuum radiation chamber V_1 and was heated electrically by leads sealed into the base of the chamber. The radiation was allowed to pass through the rock salt window W_4 into the large vacuum spectrometer chamber V_2 by opening the shutter S_2. The path of the rays through this analyzing chamber has been indicated by light lines in the figure. A concave mirror M_2 was used to focus the beam on the slit S. After having passed this slit it fell on the collimating mirror M_3 and then suffered dispersion by the rock salt prism shown at the center of the figure. It was next reflected from the Wadsworth[9] mirror M_4 to the concave mirror M_5 which in turn brought it to a focus at the exposed strip of the bolometer B. Since both of the chambers were evacuated, and all mirrors of the spectrometer were silvered on their exposed surfaces the beam of radiant energy passed through no material medium except rock salt, which, for the wavelengths considered has almost perfect transmission. By this means the loss of energy by absorption was reduced to a minimum and in all cases where it was not negligible, corrections were computed and applied to the data.

Four pumps were used for exhausting the two vacuum chambers. Three of these, indicated diagrammatically in Fig. 1, were of the following types: P_1 a Gaede vane pump, P_2 a Gaede mercury pump, and P_3 a rotary molecular pump, built by J. P. Foerst, Mechanician, University of Wisconsin. The fourth pump, not shown in the diagram, was of the rotary oil immersed variety and was placed in the vacuum line of the spectrometer chamber, for the purpose of securing better control of the pressure in the space around the bolometer.

The preparation of the test specimens was as follows: A sheet of the metal, whose spectral energy distribution was desired, was rolled out until it was about 0.04 mm thick. After this it was carefully polished and cut to size, usually about 12 mm wide and 50 mm long. It was then folded over into a black body wedge[10] having an angle of 12 deg. and was mounted vertically by clamping its ends in special machined blocks so constructed as to keep the angle of the V fixed. These clamps served also as current leads for electrically heating the radiating strip to any desired temperature. The lower one was equipped with a mechanism for moving it slowly up or down in

[9] *Philosophical Magazine*, 38-337-1894.

[10] C. E. Mendenhall, *Astrophysical Journal*, 33-91-1911.

order to compensate for temperature variations in the length of the strip.

The orientation of the specimen when in position was such that the opening of the black body V was in the direction of the glass window W_2, while one of the flat polished surfaces faced the aperture leading into the spectrometer chamber. In this position the true temperature of the metallic strip could be determined with an optical pyrometer, by sighting into the black body crevice at the same time that the bolometric apparatus was being used for measuring the characteristic emission which the polished surface was radiating to the analyzing apparatus.

The length of specimen necessary to form an image of sufficient magnitude to cover the entire opening of the spectrometer slit was a little more than a centimeter, but as the clamped ends were cooled to some extent by conduction, it was essential to use a considerably greater length than this in order that the entire portion which illuminated the slit might be at the same temperature. After deducting the amount covered by the clamps, the specimens which were used still presented a radiating surface of about 4.5 cm length, or approximately four times the length required to fill the slit. This size usually gave very satisfactory results, but in some cases, a difference of several degrees could be detected by means of the optical pyrometer when exploring a section of one centimeter length chosen near the center of the specimen.

The width of the spectrometer slit was 0.312 mm, this being the opening whose monochromatic image would just cover the exposed strip of the bolometer. The spectra resulting from an aperture of this magnitude are, of course, somewhat impure and in consequence give wavelength-energy curves which are a little too flat in regions of great curvature; consequently it is necessary in instances where the final results are affected appreciably, to reduce the curves to a pure spectrum basis. The manner of making this reduction in the present work was by means of the graphical method which has been worked out by Runge[11].

The bolometer was mounted in a double walled brass shell, which had its annular space filled with water through an opening which was afterwards sealed. This served the purpose of giving it a large heat capacity, thus eliminating any rapid changes of temperature, which might affect the dependability of the apparatus. In order to secure uniformity in regard to radiation and convection constants, the exposed and shielded strips of the bolometer were made as nearly alike as possible, each being composed of blackened platinum foil 0.002 mm thick, 0.48 mm wide, and 12 mm long, and each having a resistance of approximately 2.6 ohms. These strips formed two of the arms of a Wheatstone Bridge and were connected to the rest of the circuit as shown in Fig. 1. In order to minimize the effect of temperature changes on the resistance of the two external arms of the bridge R_5 and R_6, they were constructed of manganin wire, wound on a water-filled metal cylinder 10 cm in diameter and 10 cm long, and were immersed in a tank of oil. Each of these coils had a fixed resistance of approximately 17.7 ohms. The balancing of the bridge was accomplished by means of a large variable manganin resistance R_2 so arranged that it might be thrown in

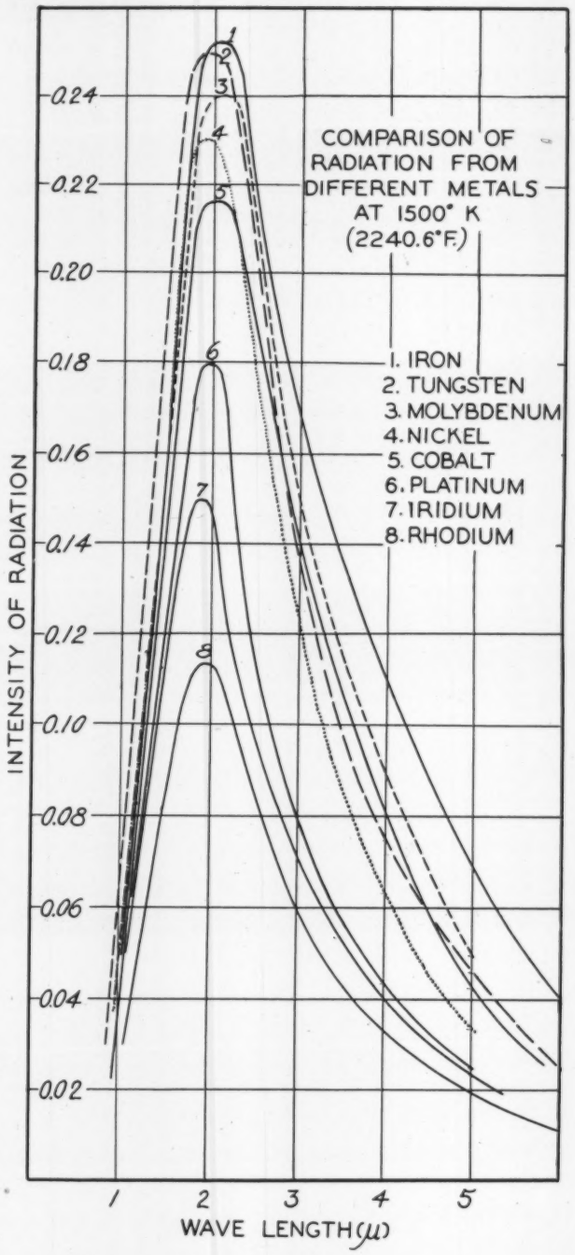

FIG. 2—COMPARISON OF RADIATION FROM DIFFERENT METALS AT 1500 K

parallel with either R_5 or R_6. A high sensitivity shielded galvanometer connected across the bridge was used for determining this balance and also for measuring, by the magnitude of the deflection from the position of balance, the intensity of the radiation of the wavelength interval which was caused to fall on the exposed bolometer strip by the opening of the shutter S_2 in the radiation chamber. A complete description of this galvanometer is given in an article by Weniger[12] on Absorption Spectra and it will, therefore, be sufficient to state here that it was of the moving magnet type, had a current sensitivity of 5×10^{-10} amperes per mm at a distance of one meter, and was adjusted so as to be dead beat. Whenever possible the instrument was used with full sensitivity, but when working at high temperatures, or at wavelengths in the

[11] *Zeitschrift fur Mathematik und Physik*, 42-205-1897.

[12] *Physical Review*, 31-393-1910.

vicinity of maximum emission, it was necessary to reduce this by switching in one of a number of definite series resistances. The following is a list of the factors by which it was found necessary to increase the galvanometer readings in order to reduce to the same basis the data taken on the different sensitivity steps:

First sensitivity— 1.00 × deflection
Second sensitivity— 2.68 × deflection
Third sensitivity— 4.83 × deflection
Fourth sensitivity— 9.15 × deflection
Fifth sensitivity—17.93 × deflection
Sixth sensitivity—36.22 × deflection

These factors were determined by taking a large number of comparison readings over the entire period during which this experimental work was carried on, several of them being taken each time that a run on a specimen was made, in order that no change might creep in without being detected.

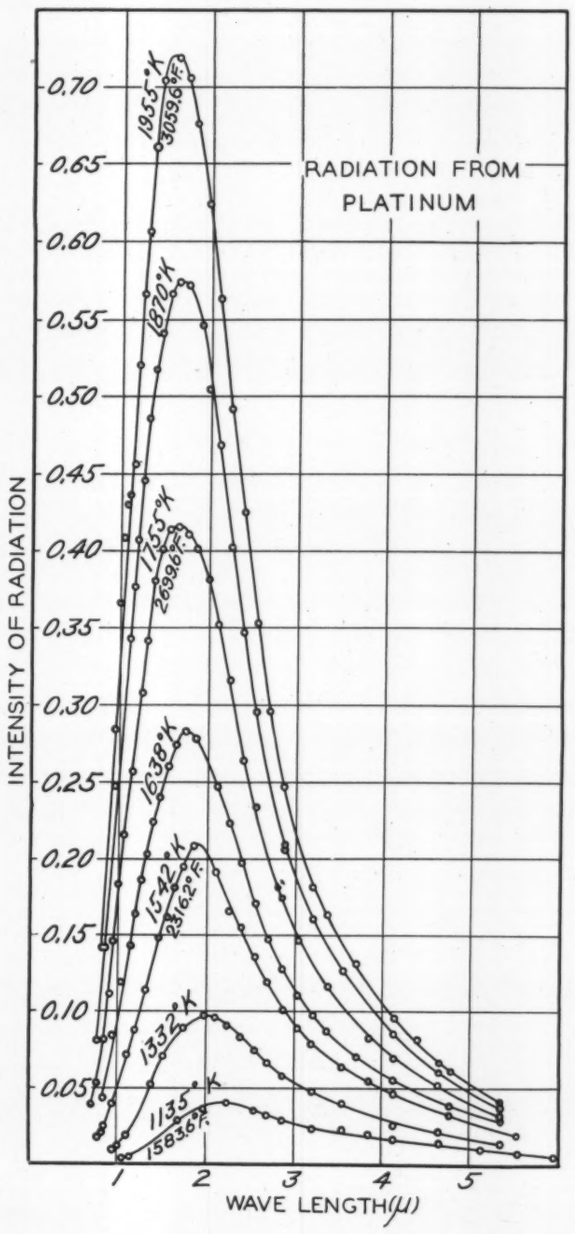

FIG. 3—RADIATION FROM PLATINUM

The Standard Lamp

The entire bolometer and galvanometer system was standardized by means of an electric comparison lamp, shown at L in Fig. 1. The purpose of placing it at this position inside of the spectrometer chamber was to have it instantly available for checking the energy measuring system at any time during a run, without the necessity of disturbing any of the apparatus, or even cooling the heated test specimen. The lamp was of the small low voltage carbon variety having a single loop filament, such as is commonly used for optical pyrometric work. After having been carefully aged this lamp was mounted inside of a series of coaxial cylindrical shields in such a manner that its radiation was completely cut off from the apparatus in the chamber with the exception of a small beam from the central portion of the filament which was allowed to shine on the bolometer strip by passing through a series of apertures in the shields previously mentioned. The radiation from the standard lamp was cut off by means of an electro-magnetic shutter which closed the outer aperture. Any desired variation in the intensity of the light was produced by means of the control resistance R_4.

In order to obtain a relation between filament current in the standard lamp and intensity of radiation falling on the bolometer, a large tungsten ribbon lamp was mounted just outside of the window W_1 with a lens so placed as to produce an image of the strip at the position S_1, which is normally occupied by the black body V. The ribbon lamp was heated to an arbitrarily chosen brilliancy, and its effect on the bolometric system obtained by opening the shutter S_2. As soon as the galvanometer deflection had been read, S_2 was closed and a deflection of the same magnitude was again produced by direct radiation from the lamp at L. After the filament current necessary for this had been recorded, a rotating sector was placed between the ribbon lamp and the window W_2 in order to reduce the energy to a definite fraction of its original value. This comparison was again made and by continuation of the process, using a number of sectors, sufficient data were obtained to plot a curve representing filament current as a function of radiation intensity. Upon examination this graph proved to be a parabola and consequently the following relation holds:

$$R = K\,(I - I_0)^2 \qquad (5)$$

where

R = intensity of radiation,
K = a constant.
I = current at any time,
I_0 = value of I at the point of tangency of the curve and the current axis.

The point I_0 was obtained accurately by plotting the square root of the radiation intensity, against filament current and taking the intercept on the current axis. This gave $I_0 = 0.193$ amp. All radiation curves for the different metals were reduced to the same energy scale, but since this scale was arbitrarily chosen the constant K of the calibration equation was dropped out, thus reducing the relation to

$$R = (I - 0.193)^2 \qquad (6)$$

Protection of the Metal Specimens

As the presence of active gases and vapors is damaging to most metallic filaments at high temperatures, special

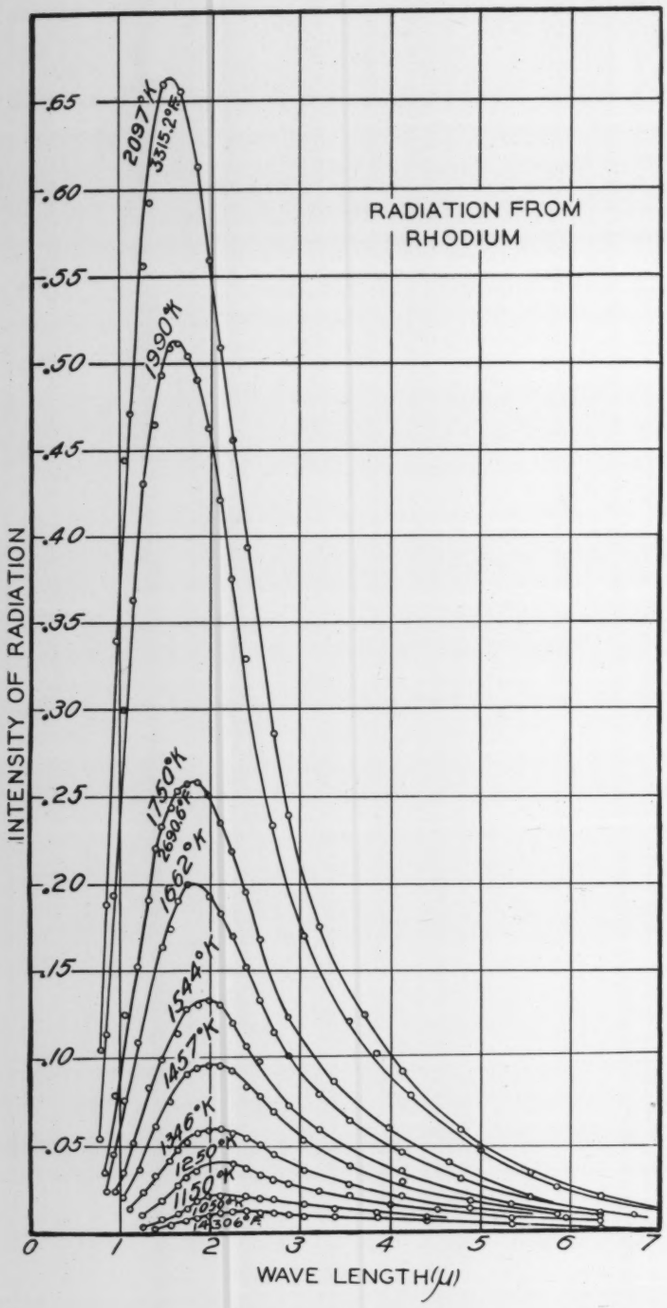

FIG. 4—RADIATION FROM RHODIUM

methods for gas elimination were used throughout this work. By means of the series of vacuum pumps mentioned above, it was possible in most cases to keep the pressure in the radiation chamber down to 0.0001 or 0.0002 mm of mercury. At the highest working temperatures, however, the vacuum fell somewhat below this value on account of the *out-gassing* of the inside walls of the chamber due to superficial heating by absorbed radiation.

In order to eliminate grease and oil vapors as far as possible, the opening in the bottom of the radiation chamber for the replacement of specimens was rendered gas-tight by means of lead gaskets instead of wax. The liquid air trap indicated at *T* in Fig. 1 served to prevent the diffusion of oil and mercury vapors from the pumps and pressure gage back into the radiation chamber. This trap was made of metal and was connected by means of metal tubing directly to the radiation chamber in order that any vapors from the wax joint between it and the glass vacuum line might be kept away from the heated specimen. During all runs this trap was kept immersed in a Dewar flask of liquid air.

The removal of water vapor from the radiation chamber was accomplished in the ordinary manner by means of phosphoric anhydride. It was found that in the use of this compound, one precaution was necessary in order to avoid shortening the life of the test specimen; namely, that of shielding the surface of the drier from intense direct radiation. If this precaution were not observed the inside wall of the chamber as well as the glass and rock salt windows would become coated with syrupy phosphoric acid, and the specimen, if of an oxidizable material, would disappear rapidly. The probable action that takes place in such a case is that the globules of orthophosphoric acid present on the surface of the anhydride are reduced by the strong radiation to metaphosphoric acid, which in turn evaporates and after being condensed on the cool inside walls of the chamber again takes up the water previously driven off, thus forming once more the viscous semi-solid compound. The destruction of the filament is evidently accomplished by some cyclical oxidizing and reducing process resulting from the disso-

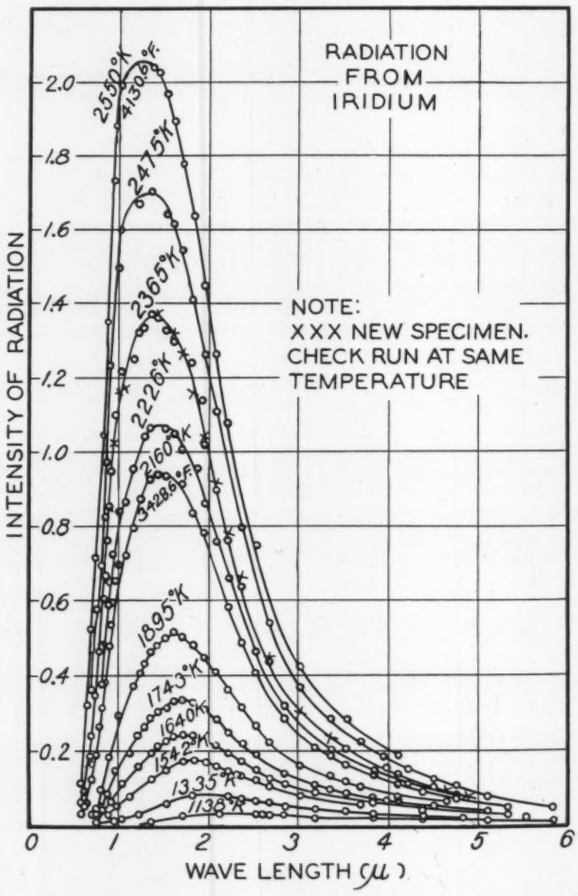

FIG. 5—RADIATION FROM IRIDIUM

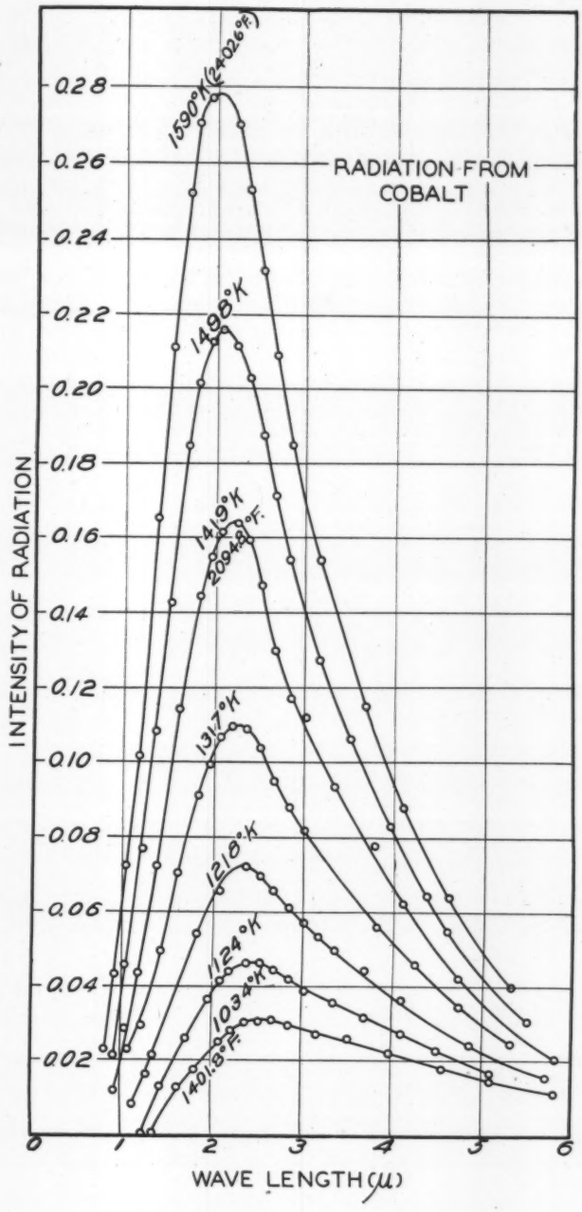

FIG. 6—RADIATION FROM COBALT

ciation of the vapors which come in contact with the hot metal. This phenomenon only occurred during runs at very high temperatures and was completely eliminated in all cases by the use of a thin metal shield to cut off the direct radiation from the drier.

General Precautions

The purpose of evacuating the large chamber V_2, Fig. 1, containing the spectral apparatus, was principally for the elimination of the absorption of energy by water vapor, carbon dioxide, and oxygen of the air. Consequently it was not necessary in this case to maintain as high a vacuum as was required in the radiation chamber. It was, however, found to be very essential, when using a low working pressure, to keep it absolutely constant since, as is well known, the sensitivity of the bolometer for pressures less than one millimeter of mercury is very materially affected by small variations of this nature. Throughout the present work the pressure in this chamber was kept constant at 0.1 millimeter of mercury.

Since water vapor is removed very slowly by the ordinary vacuum pump, a further assurance of its elimination was obtained by placing open trays of phosphoric anhydride and also of concentrated sulphuric acid at various places inside the vacuum chamber.

In order to guard against the possibility of absorption, due to the collection of a film of water on the surface of the rock salt window W_4 when preparing it under conditions of high atmospheric humidity, a convenient method suggested by M. H. Petersen was followed; namely, that of grinding and polishing under toluene. During all of this process the further precaution was observed of using rubber gloves when handling the window, in order to prevent any clouding of the polished surface by moisture from the fingers. When the polishing was completed, the window was put in place as quickly as possible and was kept protected on both sides by the use of phosphoric anhydride. Whenever the radiation chamber was opened for the purpose of replacing specimens, it was filled with dry air, and then, during the time of mounting up the new metal strip, the hole in the base of the chamber was kept closed by means of a temporary cover for the elimination of air currents.

Contamination of the silvered surfaces of the spectrometer mirrors by the diffusion of mercury vapor into the chamber from the vacuum line was prevented by a tube 6 cm in diameter and 20 cm long, which was packed loosely with a mixture of glass wool and gold leaf and was attached to the inside wall of the chamber at the point where the glass vacuum line entered. In this way any vapors coming into the spectrometer chamber were caused to flow over a large area of gold surface before reaching the apparatus inside.

Temperature Measurements

As has already been stated, the true temperatures of the metals studied were determined by means of an optical pyrometer. The instrument used for the purpose was built by J. P. Foerst, mechanician, and was very

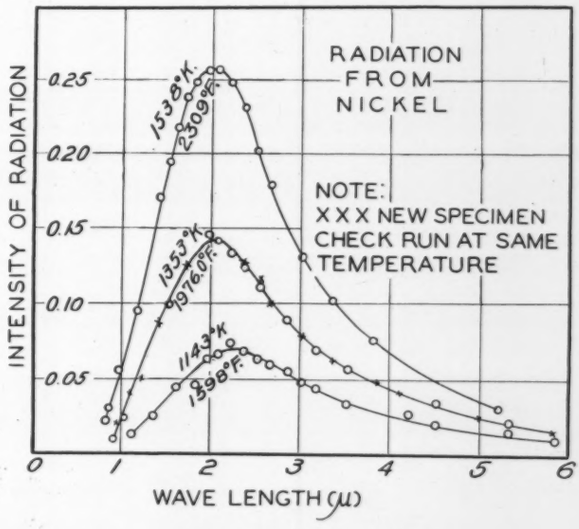

FIG. 7—RADIATION FROM NICKEL

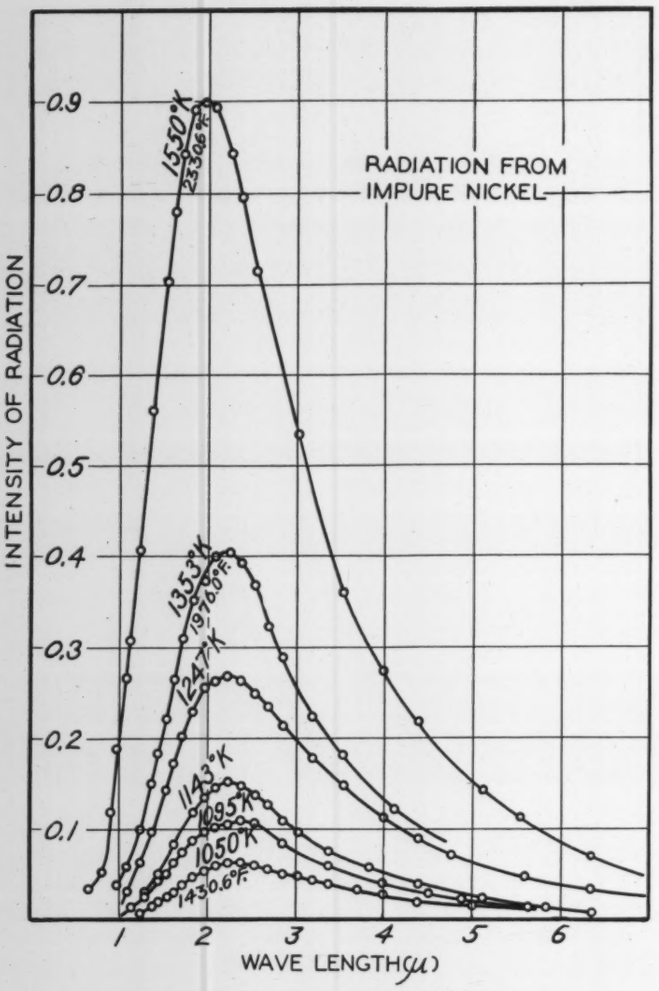

FIG. 8—RADIATION FROM IMPURE NICKEL

similar to one described in the Astrophysical Journal[13]. It was a modification of the Morse type employing rotating sectors to adapt it for use over wide ranges of temperature, and selective transmission screens for obtaining the color match necessary when computing the results by means of Wien's distribution equation. For all except the lowest temperatures measured, a green filter consisting of three layers of gelatin screen was used. The visible transmission of this screen, for black body radiation of a certain temperature, was obtained by first analyzing it spectrophotometrically[14] and then, after making the necessary reduction to black body distribution, combining the results so obtained with Ives[15] curve for the sensitivity of the eye as a function of wavelength. By using different temperatures, a number of these transmission graphs were plotted, from which, by means of a planimeter, the following effective wavelengths of transmission were obtained:

λ (Effective) = 0.5362 μ for 1000 K.
λ (Effective) = 0.5355 μ for 2000 K.
λ (Effective) = 0.5351 μ for 3000 K.

It may be seen from these results that temperature changes produce only slight shifts in the visible transmission of the screen. This characteristic is due largely to the narrowness of the transmission band of the material. It transpires also that these results are nearly independent of lack of precision in the value taken for the quantity C_2 of Wien's equation as used in making the reduction to black body distribution mentioned. By assuming first that this constant is equal to 14300, and then to 14570, a difference of less than $5 \times 10^{-5}\mu$ is produced in the computed values of the effective wavelengths of transmission. W. E. Forsythe reported several years ago[16] on some green pyrometer screens made of glass, which seemed to be somewhat unsatisfactory due apparently to the broadness of the transmission band, for he found that when using reduction sectors of small aperture the nature of the light coming from the source was so different from that emitted by the comparison lamp that a good color match could not be obtained. Very little difficulty of this nature was experienced in the case of the gelatin screens used in the present

[13] W. E. Forsythe, *Astrophysical Journal*, 43-295-1916.

[14] Two specimens of the screen, procured from the manufacturers at different times, were analyzed independently for transmission by Dr. C. E. Mendenhall and by the author, and were found to agree in effective wave-length of transmission to 0.0002μ.

[15] *Philosophical Magazine*, 24-860-1912.

[16] *Journal of the Optical Society of America*, 5-85-1921.

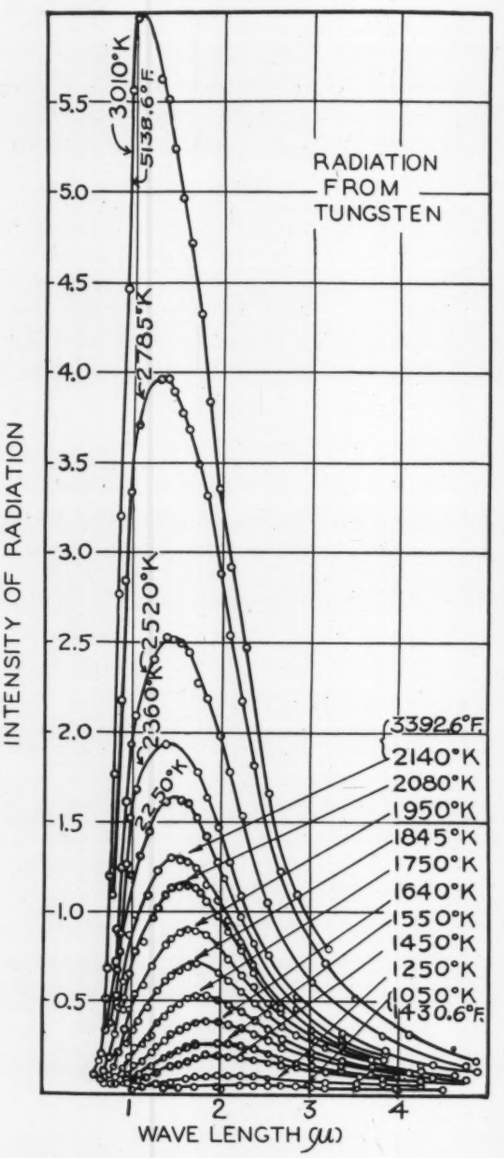

FIG. 9—RADIATION FROM TUNGSTEN

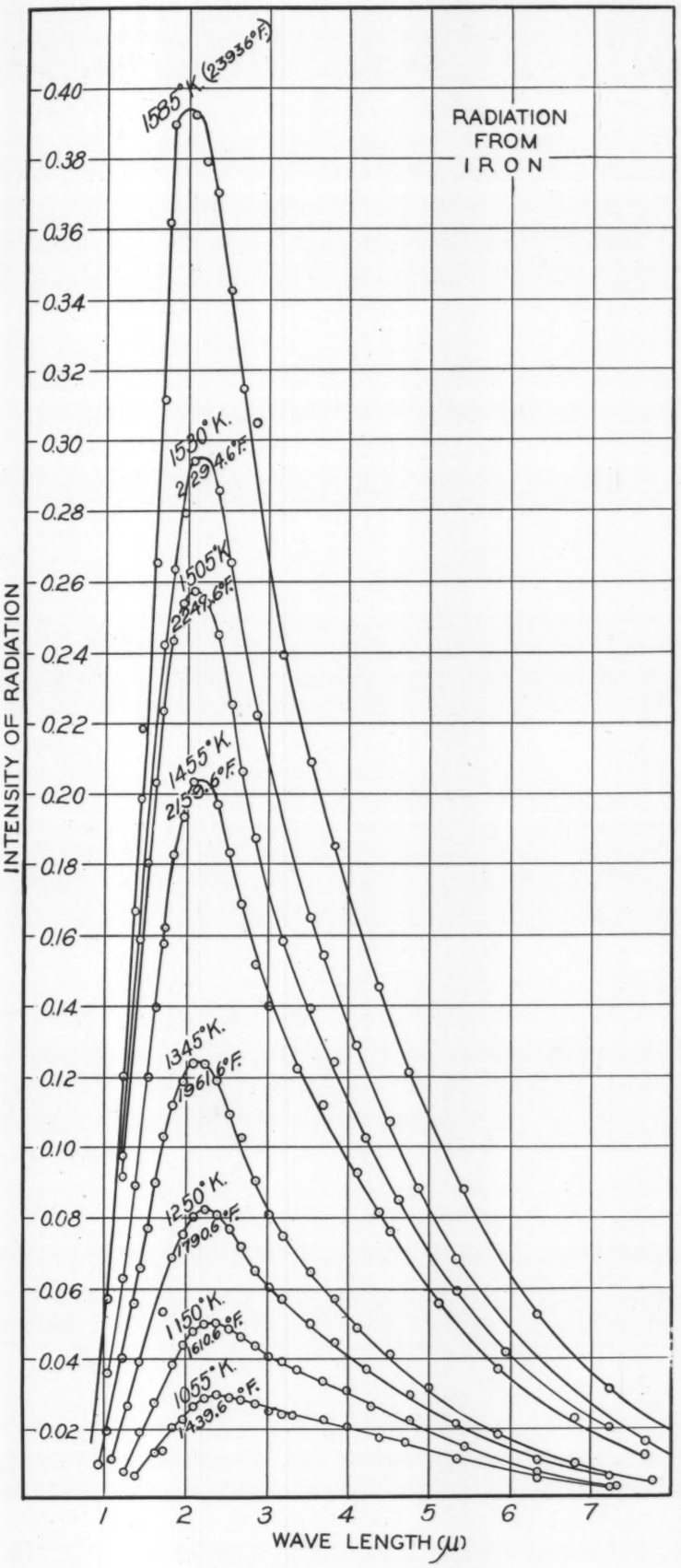

FIG. 10—RADIATION FROM IRON

work and it is believed that their transmission is sufficiently narrow to make them somewhat superior in this respect to the green glass examined by Dr. Forsythe. It is possible, however, that in regard to permanence, the gelatin screens may not be as good as those made of glass containing a body color.

For the measurement of temperatures below 1500 K it was found to be infeasible to make use of green filters on account of the small amount of green light emitted by the source. In such cases a standard red screen of Jena glass No. F-2745 was employed. The effective wavelength of transmission of this filter for the range of temperature used was obtained from the work of Hyde, Cady, and Forsythe[17] of the Nela Research Laboratory.

The optical pyrometer was calibrated by using rotating sectors for changing the intensity of a beam of light coming from a black body furnace, of a type described elsewhere[18], which was maintained at constant temperature. The value selected for this in the case of the green calibration was the melting point of palladium which was assumed to be 1822 K as determined by Day and Sosman[19]. In the case of the red calibration for low temperatures, the gold point (1336 K) was used. These standardizing temperatures were obtained by running a number of melts inside the black body chamber of the furnace, making use of what has been termed the *wire method*. In spite of the fact that the pyrometer comparison lamp was carefully *aged* at full brilliancy for a period of several days before being calibrated, it was found to change gradually with use, thus necessitating an occasional recalibration. This was made every two weeks during the time that the instrument was being employed. On account of this lamp variation some of the temperature measurements are probably somewhat in error. This error is negligible for the lower determinations, perhaps one degree at 1400 K, and possibly as much as 10 deg. at 3000 K. The comparison lamp used in the pyrometer was especially constructed for the purpose, being made with a single 4-mil tungsten filament having a slight kink near the middle for use in locating the point at which the color match was to be secured. When the pyrometer was used with the green filter the current required by the comparison lamp in covering the necessary temperature range varied from 0.63 to 0.97 amp., while with the red glass screen the variation was from 0.42 to 0.55 amp. Thus the largest current used was well below 1.5 amp., the rated full current for the lamp.

Summary and Conclusion

The radiation curves for the different metals (Figs. 2 to 12, inclusive) have been corrected for galvanometer drift, impurity

[17] *Astrophysical Journal*, 42-299-1915.
[18] C. E. Mendenhall, *Physical Review*, 10-518, 519-1917.
[19] *American Journal of Science*, 29-93, 161-1910.

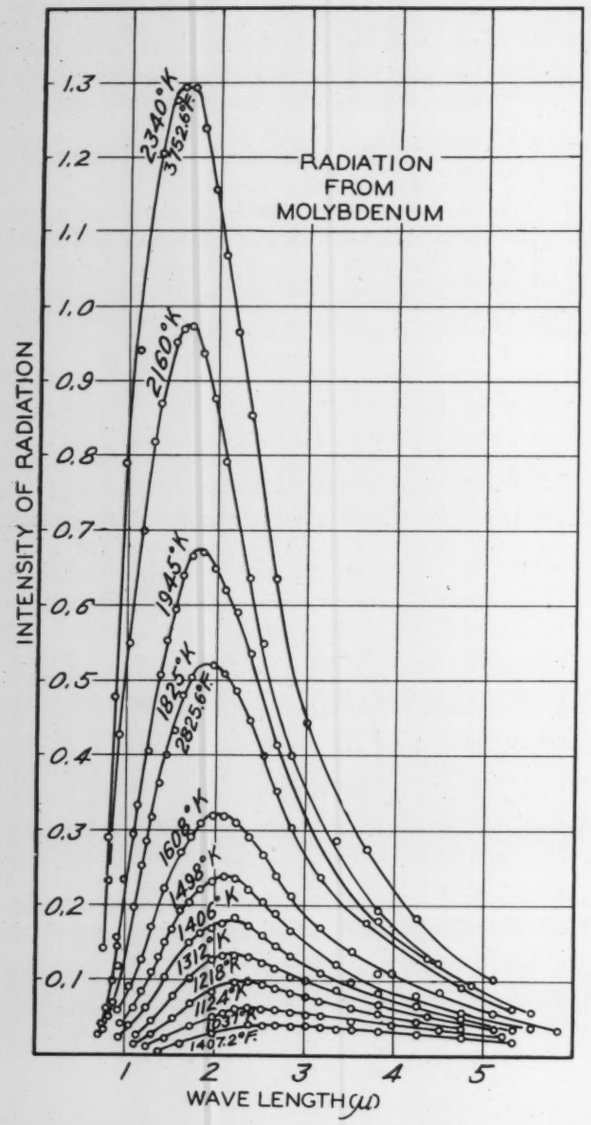

FIG. 11—RADIATION FROM MOLYBDENUM

of spectrum due to width of spectrometer slit, change of bolometer sensitivity due to slight pressure variations in the vacuum chamber, absorption of energy by the rock salt window and prism, and for variations in spectral concentration due to the non-linear dispersion of rock salt. Corrections, to the data, have also been applied for change in the reflecting power of the silver mirrors as a functon of radiation wavelength, and for change in the reflecting power of the surfaces of the rock salt prism as a function of the angle of incidence of the beam. Furthermore, the curves have been reduced to a common energy basis by comparison with an arbitrary standard source.

It was found that the total radiated energy, as well as the form of the wavelength-energy curve varied with the purity of the metal. The extent of this variation may be seen from the following: one specimen of commercial nickel at 1353 K (Fig. 8) had a total emission of 2.5 times that of electrolytic cobalt-free nickel (Fig. 7) at the same temperature, and the energy for the wavelength of maximum emission was 2.8 times as great. This large difference was probably due to contamination of the surface by the ash contained in the impure specimen.

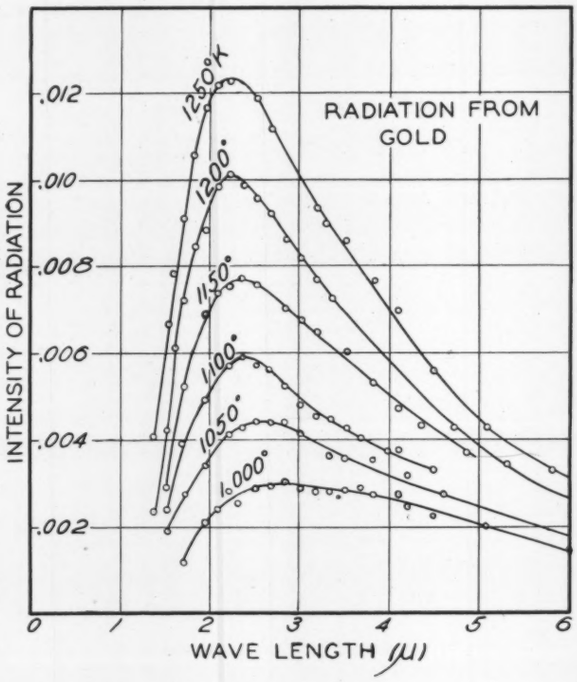

FIG. 12—RADIATION FROM GOLD

On checking the radiation equation of Aschkinass by using the set of distribution curves of the different metals at 1500 K (Fig. 2), it was found that this relation applied only very roughly to a few of the noble metals of the platinum series, while for most other metals it gave results which were not even approximately true.

Acknowledgments

The author is indebted to Prof. C. E. Mendenhall of the University of Wisconsin for many valuable suggestions and for the apparatus which his laboratory furnished; to the United States Bureau of Mines for pyrometric and furnace equipment used in checking the transmission of color screens; and to H. L. Dunham for his aid in the computation of many of the corrections which were applied to the data.

Furthermore, the experimental part of the work could not have been carried out except for the assistance of M. H. Petersen, who adjusted instruments and took bolometric readings during the entire time of obtaining data.

Some Studies on the Absorption of Noise in Ventilating Ducts

By G. L. Larson[1] (*MEMBER*) and R. F. Norris[2], (*NON-MEMBER*) Madison, Wis.

IN THE ventilating or conditioning of schools, theaters, churches, assembly halls, offices, recording studios, broadcasting studios, etc., quiet operation is essential and must be accomplished if the ventilating plant is to be considered a complete success.

The designer of the future must give more consideration to this factor than has been given in the past. The United States is becoming a noise conscious nation and as more facts about noise and its effects become known, the demand for noiseless ventilating and air conditioning systems will increase.

Many otherwise successful ventilating systems are considered failures because they create too much noise. Recently in one of the new and best ventilated churches the minister opened his talk with the remark: "Will someone please shut down the ventilating system so that I may begin my sermon."

A study of ventilating system noises is essential to successful design not only on account of the effect of noise upon human beings but also on account of the limitation that noise puts on the maximum velocities that can be used in duct design.

In buildings where space is at a premium, it is very desirable to be able to reduce the size of ventilating ducts by using velocities that are higher than those now considered good practice. The present limitations to higher velocities are (a) noise, and (b) cost of power required to produce high velocities. If noise can be sufficiently reduced by proper acoustical treatment of the ducts, then the only limitation to higher velocities is the cost of power required to produce these higher velocities.

In any given problem the value of the space saved can be balanced against the cost of the acoustical treatment plus the cost of increased power, but the very valuable item of quiet operation is hard to evaluate in dollars and cents.

Acoustical Discussion

There has been so much said in literature during the last few years about the harmfulness and wastefulness of noise, that it does not seem necessary to discuss that phase of the problem in this paper. However, a resumé of the physical nature and the causes of noise may help to clarify the remainder of this paper. Noise, such as the ear distinguishes, is a phenomenon which occurs in the surrounding air. Vibrating bodies set up pulsations in the air which cause alternating rarefactions and condensations. These proceed from the vibrating body at a velocity which depends to a slight degree on the temperature and is approximately 1,180 ft per second at 70 F. These changes in pressure are very slight in magnitude, but act upon the ear drum in such a way as to stimulate the auditory nerves which in turn convey the impression of noise to the brain. Noise in short, then, is a vibration set up in the air by some vibrating medium.

In this article, sound and noise will be considered as synonymous. From the æsthetic standpoint, music for instance would not be considered noise. However, even the best of music can be very disturbing under certain circumstances.

In ventilating work there are three major sources of noise. One is the noise generated by the fan blades passing the lip of the fan housing. The blades will cause a fluctuation in air pressure at this point which will correspond in frequency to the number of times per second that a fan blade passes the lip. In multi-blade high-speed fans this frequency can reach rather high values. The second source of noise is that generated by the motor which drives the fan. A slight eccentricity of the motor shaft will cause a wobble which will set up vibration in the machine and in the foundation. Even in the best of bearings there may be inaccuracies which will generate noise. If an alternating current motor is used the field coils may set up a hum. The third source of noise is the rush of the air through the ducts. The air going through the ducts and around bends will set up eddy curents in itself, which will produce noice and high frequency sound vibrations. This is particularly true if high velocities and small ducts are used.

Noise may be transmitted from the fan equipment in two ways. It may be transmitted through the air stream itself or as a mechanical vibration in the duct. If it is transmitted as a mechanical vibration of the duct and remains a mechanical vibration to the end of the duct, it will not cause a sensation of sound in the ears of persons occupying the rooms which the ducts serve. However, there are usually rather large areas in the ducts which can and will vibrate in response to this mechanical vibration, thus coupling it into the air at various points along the length of the duct. After the vibration has been coupled to the air it becomes audible and is transmitted through the air stream in the same way as are the other air vibrations. All of these noises may be transmitted through the ventilating system since the duct itself acts as an excellent speaking tube from the fan to the rooms which is serves. The mechanical vibration, due to the motor and the vibration of the fan, may be kept out of the duct by using a flexible connection between the fan housing and the beginning of the duct system. The noise produced by the blades of the fan passing the lip of the fan housing will be generated directly in the air stream

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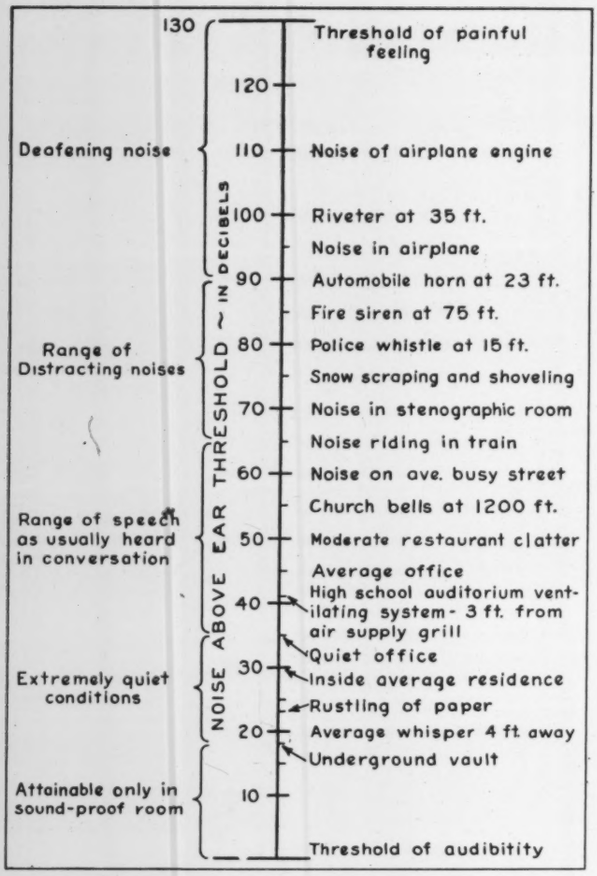

FIG. 1—LEVEL OF NOISES FROM FAMILIAR SOURCES

and will be transmitted very efficiently to all of the rooms as will be the noise generated by the air itself, due to its speed through the ducts and around bends in the ducts.

The idea of measuring sound is rather new but certain units of measurement have been established. A sound wave in the air may have the following characteristics:

A. Frequency. The sound impulses may follow each other more or less rapidly. If the impulses follow closely, one behind the other, the frequency or pitch of the sound will be high. If the impulses are spread out so that each follows its neighbor by greater time intervals, the pitch of the sound will be low. A person having normal hearing can hear sounds ranging from 32 impulses per second to 15,000 impulses per second. This range of frequency is termed the audible range.

B. Amplitude. A sound wave of any one frequency may differ from another sound wave of the same frequency by having a different amplitude. In other words, the maximum variation of pressure of one sound wave will be greater than the maximum variation of pressure in the other. The sound wave having the greater variation in pressure will sound louder to the ear. In measuring sound the amplitude of the sound wave is not usually measured as such, but measurement is made of the intensity of sound, which is the total energy of sound. The intensity ratio of the loudest sound which the ear can stand to the softest sound that the ear can recognize as such, is greater than one billion to one. The human ear does not respond directly to the intensity of the sound but rather responds to the logarithm of intensity. For this reason it was necessary to develop a unit of loudness. This unit has been called the *decibel*. Mathematically the decibel may be expresed as

$$10 \log_{10} \frac{I_1}{I_0}$$

Where I_1 and I_0 are two intensities, I_0 being the intensity from which the loudness of the sound is measured. In acoustical measurements, I_0 is usually taken as that intensity which is just barely audible in an absolutely quiet room. This value is called the threshold of hearing and is represented by zero on the decibel scale.

Physically an increase or decrease of loudness of one decibel is the smallest increase or decrease that can be detected by the ear. Consequently, if one sound is louder by one decibel than another it will be just noticeably louder. Ten decibels increase in loudness represents an intensity increase of ten to one, twenty decibels increase in loudness represents an intensity increase of one hundred to one, and thirty decibels increase in loudness represents an intensity increase of one thousand to one, etc.

Fig. 1 shows the loudness of some familiar noises on the decibel scale.

Object of Tests

The object of the tests reported in this paper was to determine the effect upon sound intensity of various arrangements of acoustically lined and unlined ventilating ducts and the effect of such lining upon resistance to air flow at air velocities varying from 500 to 5,000 ft. per minute.

Description of Test Apparatus

The 30-ft. duct which was used for these tests was made up of interchangeable 2-ft. sections. Each section was 10 by 10 in. on the inside. This permitted various combinations ranging from all lined to all unlined ducts. The test duct is shown in Fig. 2 with nine sections (18 ft.) of unlined duct at the intake end and six sections (12 ft.) of lined duct at the discharge end. One of each of the two types of section is shown in Fig. 3. The duct metal was galvanized and No. 26-gage thickness. Each

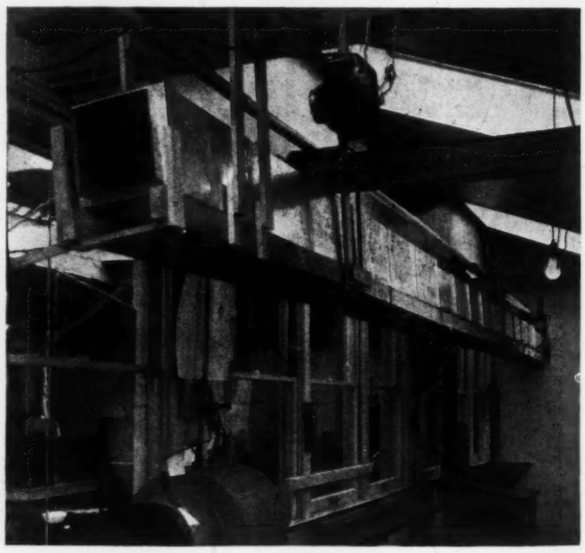

FIG. 2—THIRTY FEET OF TEST DUCT EXTENDING FROM SOUND PROOF PARTITION

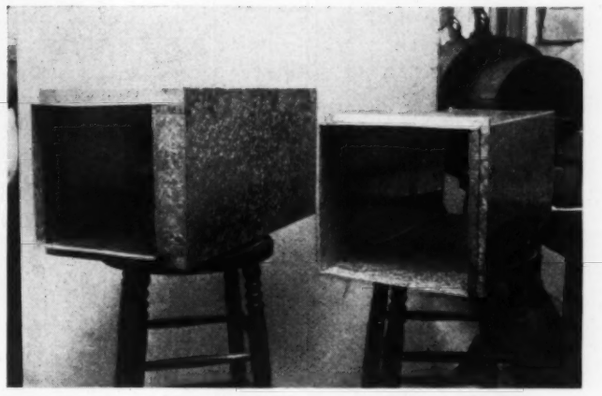

FIG. 3—CONSTRUCTION OF TEST DUCT SECTIONS

2-ft. section of unlined duct had a stiffener rib at one end. The lined sections had an enlarged casing on the outside 12 by 12 in. This provided a cavity one inch thick into which a one-inch layer of wood fibre insulating blanket was laid. This blanket was covered on the inside with perforated metal which had 32 holes per square inch. These holes were 0.075 in. in diameter and were made by punching. Another scheme of lining was used whereby the wood fibre insulating blanket was held in the duct by four ¾ by ¾-in. angles cut from the perforated metal.

In order to make certain that the measured ventilating noises were all coming through or from the duct, the blower and motor drive were completely boxed in with sound insulating material, as shown in Fig. 4. The fan was connected to a 12-in. circular metal duct by means of rubber lined canvas. After a 3-ft. radius right angle turn, there was 10 ft. of straight pipe before a Pitot tube station. Beyond this station, there was 4 ft. of circular pipe followed by a 3-ft. adapter section which connected the 12-in. round duct to the 10-in. square test duct. Between the Pitot tube station and the adapter section, a sound partition was constructed. This wall was heavily covered on the fan side with acoustical insulation, and it completely separated the fan room from the room in which the test duct was located. A part of this wall is shown in the background of Fig. 2. All windows and doors to both rooms were kept closed throughout all tests.

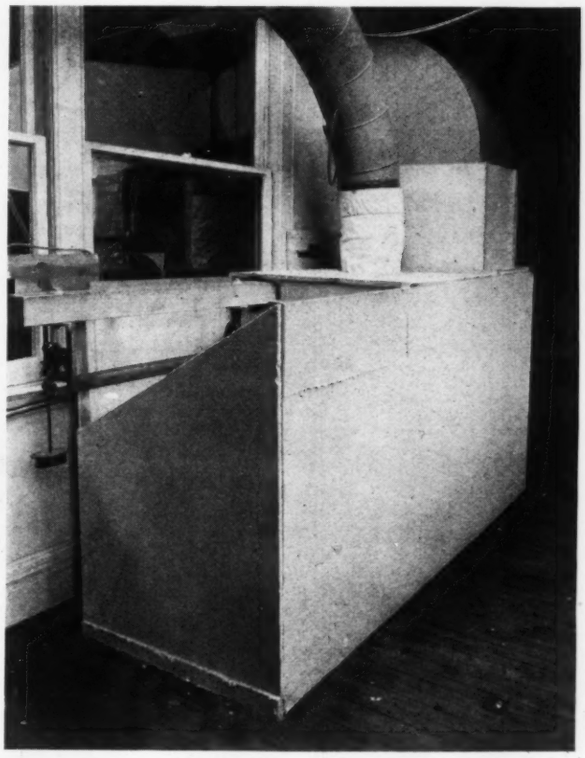

FIG. 4—ACOUSTICAL HOUSING OF FAN AND DYNAMOMETER SHOWING SLEEVE CONNECTION TO DUCT

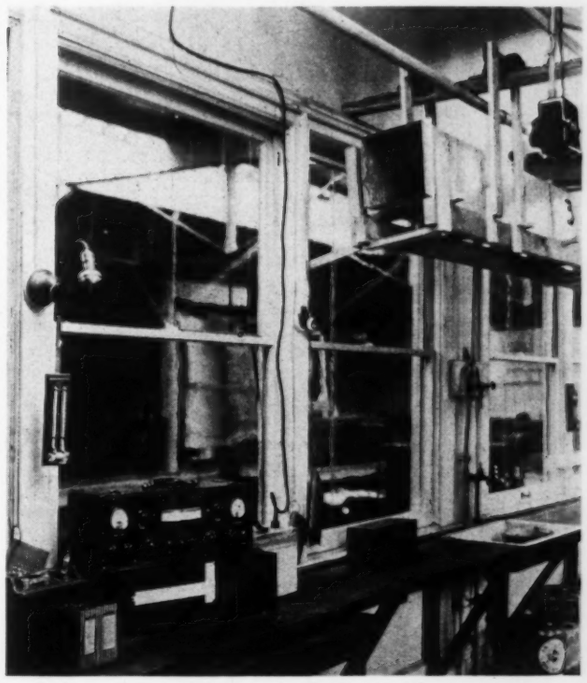

FIG. 5—ARRANGEMENT OF MICROPHONE AND ACOUSTIMETER FOR MEASURING NOISE LEVELS

The brake horsepower required by the fan motor was measured by a scale beam connected to the dynamometer mounting of the motor frame. The beam is shown in Fig. 4. The fan speed was determined by means of a calibrated electric tachometer. The air flow was measured by means of a Pitot tube and Wahlen gage. The Pitot tube was of standard construction. The Wahlen gage is a very sensitive differential gage capable of measuring pressures up to one inch with an accuracy of 0.001 in. of alcohol.

The measurement of noise was accomplished by means of a microphone and acoustimeter set up as shown in Fig. 5. The microphone was placed 2 ft. from the center of the test duct at right angles to and in line with the outlet end. Both the microphone and the electrical cord connecting it to the acoustimeter were supported in such a manner as to avoid any foreign vibrations which might affect the acoustimeter readings.

The acoustimeter is comprised of a condenser microphone, a special amplifier and a thermal ammeter. Sound waves striking the microphone generate an electric wave which is proportional to the amplitude of the sound wave. This electric wave is amplified and then impressed on the

Each Section 2'-0" long and 10"×10" inside.
U = Unlined duct.
M = Acoustically lined duct- perforated metal and wood fibre blanket.
L = Acoustically lined duct- wood fibre blanket.

Test No.	Section Number ←Discharge												Intake→		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
2	U	U	U	M	M	M	M	M	M	M	M	M	M	M	M
3	U	U	U	U	U	U	M	M	M	M	M	M	M	M	M
4	U	U	U	U	U	U	U	U	U	M	M	M	M	M	M
5	U	U	U	U	U	U	U	U	U	U	U	U	M	M	M
6	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
7	M	M	M	U	U	U	U	U	U	U	U	U	U	U	U
8	M	M	M	M	M	M	U	U	U	U	U	U	U	U	U
9	M	M	M	M	M	M	M	M	M	U	U	U	U	U	U
10	M	M	M	M	M	M	M	M	M	M	M	M	U	U	U
11	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
12	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
13	M	M	M	U	U	U	U	U	U	U	U	U	M	M	M
14	M	U	M	U	M	U	M	U	M	U	M	U	M	U	M
15	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
16	U	U	U	U	U	U	U	U	U	U	U	U	M	M	M
17	M	M	M	U	U	U	U	U	U	U	U	U	U	U	U
18	U	U	U	U	U	U	L	L	L	L	L	L	L	L	L

Fig. 6—Outline of Tests and Duct Arrangements

heater of a vacuum thermal couple. The thermal couple generates a current which is proportional to the square of the impressed wave. This current is measured by means of a very sensitive micro-ammeter. Since the intensity of the sound wave is proportional to the square of its amplitude, the reading of the micro-ammeter is directly proportional to the intensity of the sound.

Method of Procedure

The first test was made with the entire duct built up from sections which were lined with both the acoustical material and the perforated metal. Each test consisted of four runs at fan speeds of 200, 500, 800 and 1,100 rpm to furnish a wide range of air velocities.

The second test was made after replacing the three lined sections at the outlet end with unlined sections. The third test was made after replacing three more lined sections with unlined sections, resulting in a duct with six unlined sections at outlet. This procedure was followed throughout the first series of six tests. This series covered a range from all lined duct to all unlined duct in increments of 6 ft. During each run for each of the six tests, both sound and air measurements were taken. The procedure for each of these tests was as follows. After the speed of the fan had been adjusted, two observers in the fan chamber observed speed of fan, load on torque scale, differential pressure across fan, and static pressure at Pitot tube station. The Pitot-tube readings were taken at 20 points in the 12-in. diameter round pipe. The readings were in thousandths of an inch of alcohol as read on the Wahlen gage. The twenty observation points in the duct included a horizontal and a vertical

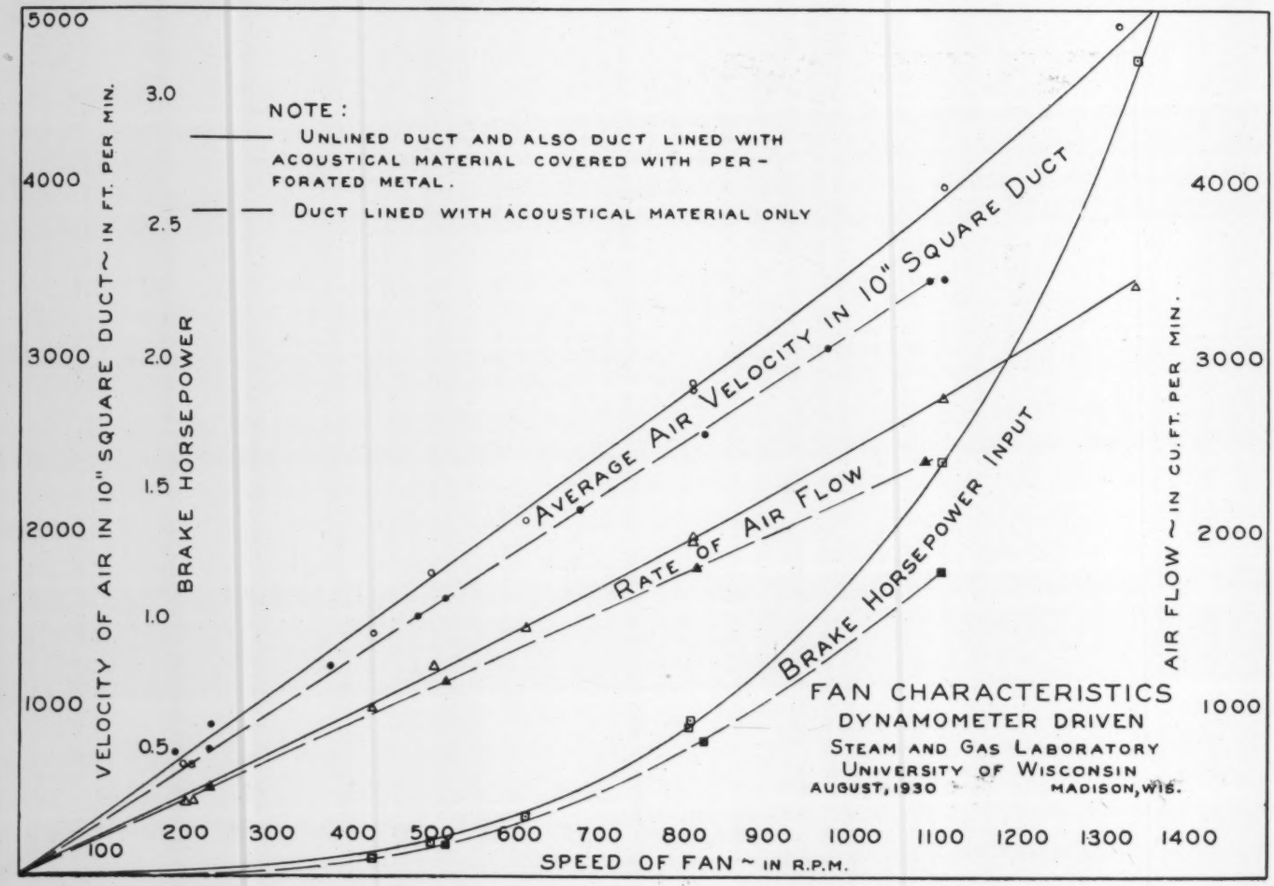

Fig. 7—Air Flow Curves

traverse with definite points located mathematically so that four values of velocity head were taken for each of five equal areas of cross section. From these readings and the air density, the average velocity head was determined. A third observer stationed at the acoustimeter in the duct room took a series of observations of the noise intensity.

Each of the first six tests showed the same air flow and the same horsepower required by the fan. Since the tests included six combinations varying from all lined to all unlined duct, the air was not measured for the succeeding tests involving other combinations of the same duct sections. Thus several tests were made by adjusting the speed of the fan and observing the noise intensity. Five such tests obtained data for combinations where the amount of lining at the outlet was varied in increments of three sections of duct (6 ft.). The various duct arrangements for each test are shown by Fig. 6.

After all tests involving perforated metal lining had been completed, the perforated metal was removed from the lined ducts and the acoustical material held in by four perforated metal angles placed at the corners. During the tests involving this type of lining, both air and noise measurement observations were taken.

For the higher velocities it was a simple matter to measure the noise intensity; but for the low velocities, and especially the series involving lined duct, foreign noises interfered. For this reason, it was necessary to make these tests at night when more quiet conditions could be obtained. Tests were repeated until an adequate check upon all results was made.

Discussion of Results

Fig. 7 shows the curves pertaining to air movement. The solid line curves were obtained from data observed during the first six tests. There was no difference between the air flow or horsepower input with unlined duct and the duct which had the perforated metal on the inside. This was not the case where the acoustical material was exposed. The duct resistance increased and this is shown by the broken line curves. The capacity of the fan for any given speed was reduced and this resulted in a lower horsepower input.

Fig. 8 shows how the noises from the various duct arrangements compare over a range of air velocities. Points are shown for only four of the curves and curves for three of the tests were not drawn in order to avoid overcrowding the curve sheet. There was not a great deal of difference in the noise intensity for several of the tests. A matter of one decibel is very difficult to measure even with the sensitive acoustimeter. The noise increases with increase of air velocity but the increment of noise increase becomes less for the higher velocities. There is a great difference between the noise from a lined duct and that from an unlined duct. For example, if the two ducts were to be operated at the same sound level, say 40 decibels, then the air velocity in the lined duct could be 1.8 times that in the unlined duct, or at 26 decibels the velocity ratio would be 2.5. At an air velocity of 800 ft. per minute there is a difference in noise of ten decibels between the full lined duct and the unlined duct, or a reduction of noise intensity of 10 to 1. Other relations can be readily obtained from the curves.

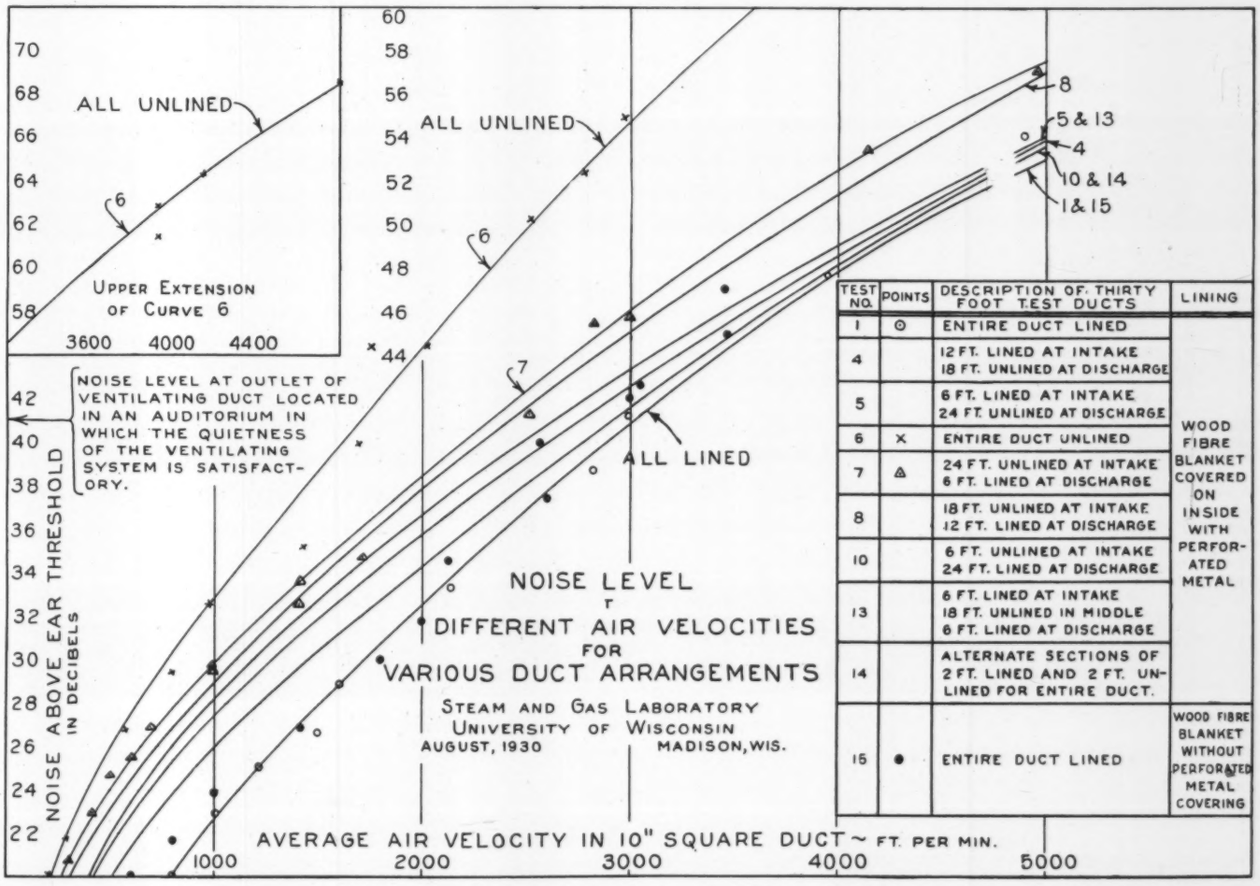
ALL UNLINED
ALL UNLINED
UPPER EXTENSION OF CURVE 6
3600 4000 4400
NOISE LEVEL AT OUTLET OF VENTILATING DUCT LOCATED IN AN AUDITORIUM IN WHICH THE QUIETNESS OF THE VENTILATING SYSTEM IS SATISFACTORY.
ALL LINED
NOISE LEVEL
FOR
DIFFERENT AIR VELOCITIES
FOR
VARIOUS DUCT ARRANGEMENTS
STEAM AND GAS LABORATORY
UNIVERSITY OF WISCONSIN
AUGUST, 1930 MADISON, WIS.
NOISE ABOVE EAR THRESHOLD IN DECIBELS
AVERAGE AIR VELOCITY IN 10" SQUARE DUCT ~ FT. PER MIN.
1000
2000
3000
4000
5000
8
5 & 13
4
10 & 14
1 & 15
TEST NO. | POINTS | DESCRIPTION OF THIRTY FOOT TEST DUCTS | LINING
1 ⊙ ENTIRE DUCT LINED
4 12 FT. LINED AT INTAKE 18 FT. UNLINED AT DISCHARGE
5 6 FT. LINED AT INTAKE 24 FT. UNLINED AT DISCHARGE
6 × ENTIRE DUCT UNLINED
7 △ 24 FT. UNLINED AT INTAKE 6 FT. LINED AT DISCHARGE
8 18 FT. UNLINED AT INTAKE 12 FT. LINED AT DISCHARGE
10 6 FT. UNLINED AT INTAKE 24 FT. LINED AT DISCHARGE
13 6 FT. LINED AT INTAKE 18 FT. UNLINED IN MIDDLE 6 FT. LINED AT DISCHARGE
14 ALTERNATE SECTIONS OF 2 FT. LINED AND 2 FT. UNLINED FOR ENTIRE DUCT.
WOOD FIBRE BLANKET COVERED ON INSIDE WITH PERFORATED METAL
15 ● ENTIRE DUCT LINED
WOOD FIBRE BLANKET WITHOUT PERFORATED METAL COVERING

FIG. 8—NOISE LEVEL CURVES

Fig. 9 shows a graphical picture of the ducts arranged in order with the most quiet arrangement first. Of course, the full lined duct ranks first and from the points shown in Fig. 8, there seems to be very little difference from a noise standpoint, whether or not the acoustical lining is covered with perforated metal. What little difference there is seems to favor the metal covering. It is quite evident that the lining placed at the inlet results in a more quiet duct than one that has the same or even more lining at the discharge. In fact, 6 ft. of lining at the inlet is slightly better than 18 ft. of lining at the discharge.

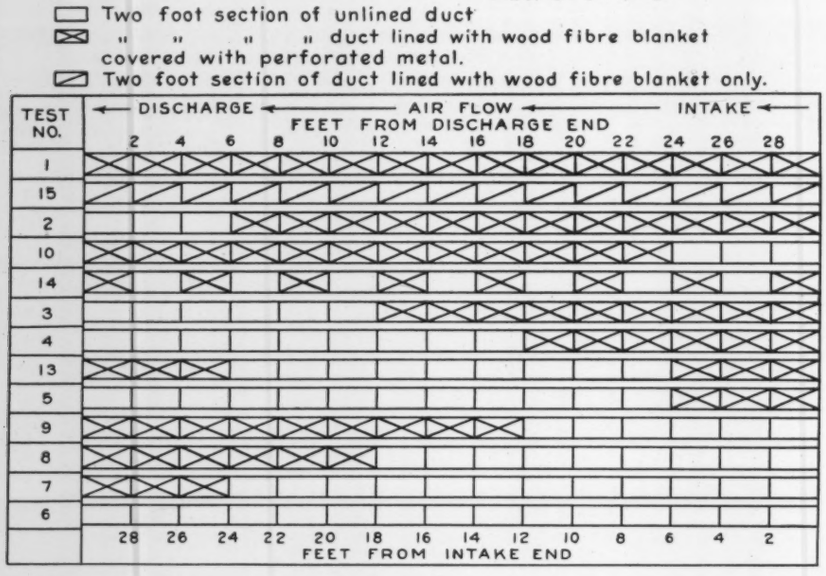

FIG. 9—ARRANGEMENT OF TEST DUCTS IN ORDER OF THEIR EFFECTIVENESS

Conclusions

It goes without saying that all noises should be eliminated at their source, if possible. Quiet motors and fans should be specified, and they should be mounted on special foundations designed for absorbing vibrations. Fans should be connected to the duct system by means of canvas connections at both inlet and outlet of fan. Endless belts should be used where motors are not direct connected to fans. In special cases, it may be necessary to treat the fan room with acoustic material.

But even if all these precautions are taken, considerable noise may be carried by the duct system from the fan room to the rooms served, or disagreeable noises may be developed in the duct system itself, particularly in systems using high air velocities. The tests show that these noises can be greatly reduced by lining the ducts with sound absorbing material. As would be expected the best results are obtained when the entire duct is lined.

When lining the entire duct is not practical, it is more economical to line at the inlet than it is to line at the outlet. The tests show that 6 ft. of lining at the inlet is more effective than 18 ft. of lining at the outlet. However, it may be necessary to place some lining near the outlet of long ducts in order to absorb noises developed in the ducts themselves.

Acoustic material with a perforated metal surface does not increase the resistance to air flow above that in an unlined metal duct. The same acoustic material without the perforated metal surface has about the same sound absorbing capacity as the other, but it has a greater resistance to air flow. Furthermore, it may disintegrate and be carried away by the air when used with high velocities.

Acoustic material applied to ventilating ducts makes it possible to use higher velocities without getting into the range of disagreeable noises.

Heat Transfer Through Metal-Inclosed Insulation

A paper entitled Heat Transfer Through Metal-Inclosed Insulation, by M. S. Van Dusen, and designated as Research Paper No. 207 of the Bureau of Standards of the U. S. Department of Commerce has recently been reprinted in pamphlet form from Bureau of Standards Journal of Research, Vol. 5, August 1930.

The paper gives a mathematical treatment of the problem of heat transfer through an insulated metal-inclosed panel, such as a sheet-metal door, consisting essentially of a sheet-metal box filled with insulating material. The treatment is necessarily approximate, but the approximations involved are accurate enough for practical purposes. The effect of a solid metal thermal short circuit, such as a supporting member extending from one metal surface to the other, is also considered.

Calculations and graphs are included, showing the relative magnitude of the heat transfer by metallic induction in a number of cases which might be considered in the design of this type of construction. It is shown that the increase in heat transfer through a metal-inclosed panel due to the presence of the metal may be as high as 100 per cent in many cases which might be considered in practical design.

The question of heat transfer through what might be termed an insulated panel, consisting of a slab of insulating material completely inclosed by sheet metal, the dimensions of the sides being large in comparison with the thickness of the panel, has been raised on a number of occasions, but the effect of metallic conduction around the edges of such a panel apparently has been a matter of conjecture.

Air Conditioning as Applied to Furniture, Fixtures and Other Interior Woodwork

By D. R. Brewster[1], Memphis, Tenn.
MEMBER

IN ITS APPLICATION to human comfort and health, the art of air conditioning has, in recent years, been developed to a high degree of refinement. Scarcely less important has been the growing appreciation on the part of ventilating engineers of the importance of air conditioning in connection with industrial processing. One of the most valuable applications of air conditioning knowledge has been in connection with the fabrication and use of the thousands of articles made from wood. The purpose of this paper is to point out some of the considerations involved in the control of atmospheric temperatures and humidities in their relation to the manufacture and utility value of furniture, fixtures and other interior woodwork.

Purpose of Air Conditioning

Wood is a hygroscopic material composed largely of cellulose. In common with other cellulose products, wood has the property of absorbing moisture from the air or giving up moisture to the air until a condition of balance is attained between the moisture content of the wood and the relative humidity of the air. Within the range of ordinary atmospheric temperatures, this condition of balance is well below the point at which the wood fibers are saturated and the fibrous structure of the wood has the property of swelling as it absorbs moisture and of shrinking as it gives up moisture. The practical function of air conditioning as it relates to woodwork is therefore to surround the wood with such a uniform atmospheric condition that this shrinking or swelling will be held to a negligible amount and the wooden article will be maintained at an approximately constant size.

In addition to changes in size, swelling or shrinking of the wood in response to changes in atmospheric humidity may also set up fiber stresses in the wood. If the moisture changes are fairly uniform, these stresses are negligible. When a wide variation in moisture content develops in different parts of the piece of wood, however, as between the two faces or between the ends and the middle, more or less distortion of shape may occur, such as cupping or twisting.

Fortunately, the atmospheric changes within buildings are ordinarily so gradual from season to season that distortion in furniture or woodwork due to fiber stresses seldom occurs under the usual conditions of use. In extreme cases, where the wood is subjected to exceptionally moist conditions, followed within a short time by exceptionally dry conditions, severe stresses may develop amounting to several hundred pounds per square inch. Separation of joints and warping are not surprising under such circumstances and may be sufficient to damage the appearance or utility value of the article concerned.

In the design and fabrication of wooden articles and woodwork, the tendency of the wood to shrink and swell with moisture changes is taken into consideration and provision is made to permit a certain amount of shrinking and swelling without injury. These provisions are not sufficient, however, to accommodate all of the changes in size and shape that may occur in the seasonal swing from outdoor conditions in the summer time to indoor conditions in heated buildings during extremely cold weather such as prevails in the northern and central portions of the United States. The assistance of the air conditioning engineer is therefore helpful to prevent damage to the furniture and other woodwork due to excessively low humidities in heated buildings as well as to prevent the development of conditions harmful to the mucous membranes and respiratory tracts of the human occupants.

Amount of Shrinkage of Wood

The shrinkage of wood shows a considerable variation in accordance with the species and density and the direction of the fibers. In changing from a condition of fiber saturation (for most woods approximately 30 per cent moisture content in terms of the oven-dry weight) to an oven-dry condition, with practically no moisture left in the wood, the shrinkage lengthwise of the fibers normally amounts to from 0.10 to 0.35 per cent and is negligible. Under the same conditions, the shrinkage across the grain in a radial direction (from the bark to the pith of the tree) ranges from 2.0 to 8.5 per cent of the original size, and the shrinkage across the grain in a tangential direction (parallel to the bark) ranges from 4.0 to 14.0 per cent.

On an average, the shrinkage in a tangential direction across the fibers is about twice as much as in a radial direction, although certain woods show approximately the same shrinkage in both directions. From the fiber saturation point to an oven-dry condition, the shrinkage is in direct proportion to the loss in moisture content and shows a straight line relationship. Thus it may be assumed that, below the fiber saturation point, each 1 per cent change in moisture content will be accompanied by

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TABLE 1—MAXIMUM AND MINIMUM AVERAGE MOISTURE CONTENT OF RAW WOOD SAMPLES UNDER INTERIOR CONDITIONS, 1928 TO 1930 [a]

CITY	AVERAGE MOISTURE CONTENT (PER CENT OF OVEN-DRY WEIGHT)		
	MAXIMUM	MINIMUM	RANGE
Washington, D. C.	11.0	7.0	4.0
Albuquerque, N. M.	8.0	5.0	3.0
San Francisco, Cal.	10.0	8.5	1.5
Portland, Ore.	8.5	7.0	1.5
Madison, Wis.	10.5	6.0	4.5
New Orleans, La.	13.0	11.0	2.0

[a] Matched samples of hard maple were used in this series of tests as representative of most of the hardwoods used for cabinet work.

approximately 1/30 of the total possible shrinkage or swelling. Obviously the seasonal changes to which wood is ordinarily subject will involve only a small per cent of the total possible shrinkage or swelling.

Research conducted by the *U. S. Forest Products Laboratory* in co-operation with the *National Lumber Manufacturers Association* during the past two years has attempted to determine the seasonal changes in moisture content and shrinkage of unfinished samples of raw wood under interior conditions in representative cities in different parts of the country. The results are summarized in Table 1.

The normal shrinkage of hard maple and other cabinet woods used for furniture and interior woodwork, from the fiber saturation point to an oven-dry condition, ranges from a minimum of about 4.0 per cent radially to a maximum of about 11.0 per cent tangentially. Under these moisture changes, therefore, the shrinkage of raw wood would vary from 5 per cent $\left(\frac{1.5}{30}\right)$ of 4 per cent to 15 per cent $\left(\frac{4.5}{30}\right)$ of 11 per cent or from 0.20 per cent radially to 1.65 per cent tangentially. With these changes, therefore, a 12-in. board would change in width between summer and winter from 0.024 in. in a radial direction in San Francisco to 0.198 in. in a tangential direction in Madison.

Shrinkage of 0.024 in. or about 1/40 of an inch in 12 in. is negligible, of course, but a shrinkage of 0.198 or about 1/5 of an inch, in 12 in. might do considerable harm to furniture, flooring and other forms of woodwork. In addition, it should be borne in mind that woodwork is frequently subjected to greater extremes (of dryness in the winter and high humidity in the summer) than the average conditions surrounding the samples in the tests summarized in Table 1. Buildings often become overheated during the winter season. As a result, humidities may drop low enough to produce a moisture content as low as 4.0 per cent in woodwork. At the other extreme, an unusually long period of hot, humid days in the summer time may be sufficient to build up the moisture in the wood to as much as 15 or 16 per cent for temporary periods.

Thus the shrinkage and swelling of the wood may, under some circumstances, be more than twice as great as indicated by the figures in Table 1. While these severe conditions are more or less unusual and abnormal, they are none the less harmful when encountered and should be considered. It is in such cases particularly that air conditioning, by diminishing extreme seasonal variations in atmospheric humidity, can be made a factor of real importance.

Protection of Furniture and Woodwork

One valuable means of protecting furniture and woodwork from damage due to moisture changes is the use of moisture resistant finishes, such as varnish, lacquer, enamel, and paint. While these finishes are all more or less porous and subject to moisture penetration, they retard the rate of moisture changes in the wood sufficiently to materially reduce the extent of the seasonal changes between summer and winter. Thus varnished or painted furniture or woodwork will show decidedly less shrinkage and swelling than unpainted raw wood exposed to the same conditions.

Moisture in finished woodwork will show a *lag* of several weeks in its response to atmospheric moisture changes and this lag may be sufficient to reduce the total seasonal variation to less than half that of unfinished wood. Much depends upon the thoroughness of the finishing and the extent to which a protective coating is used on the back side or inner surfaces of the wood. One coat of varnish on the outside surface with no back-painting or priming is of minimum value. Two coats are considerably more than twice as effective as one coat, since the second coat serves to cover the minute voids left in the first coat. Each additional coat, up to 12 coats, has been found by the *U. S. Forest Products Laboratory* to give added moisture resistance (Technical Note No. F-12.) After the fourth coat, however, the added value of the further coats was shown to be comparatively small.

Perhaps the most conspicuous examples of the value of atmospheric humidity control in the protection of furniture and woodwork occur in connection with antique furniture, wall paneling, and other woodwork imported from foreign countries. American museums and wealthy individuals have imported a considerable quantity of such material in recent years, including chairs, benches, chests, mantels, wall panels, doorways, stair railings, plank floors, beamed ceilings, desks, tables, and other articles made of wood. Often whole rooms have been removed from English and French mansions to be reassembled in American museums, homes, and private offices. Considerable damage and disappointment have resulted from the unexpected shrinkage of this furniture and woodwork when subjected to the low humidities commonly found in artificially heated American buildings in the colder sections of this country.

Atmospheric humidities, both out-of-door and indoor, are much higher in Western Europe than in most parts of the United States and the less efficient methods of heating generally employed result in considerably lower indoor temperatures during cold weather than are customary in our homes and offices and public buildings. Consequently, old furniture and woodwork comes to a balance with atmospheric humidities in European buildings at moisture contents that are rarely under 9 per cent and may be as high as 14 or 15 per cent, based on oven-dry weight, during certain seasons of the year when rain and fog are particularly prevalent.

Woodwork in this condition cannot be subjected to

the low atmospheric humidities characteristic of the winter time without an appreciable amount of shrinkage, which is often sufficient to cause damage. Humidities as low as 25 or even 20 per cent are not uncommon in steam-heated buildings in this country in sub-zero weather, where no provisions have been made for humidity control. Such low humidities may dry woodwork and furniture to a moisture content below 5 per cent if continued for several weeks. Under such circumstances, wooden articles brought over from England and France might lose as much as 8 or 9 per cent in moisture content with a shrinkage as high as 2 or 3 per cent of their original dimensions.

Damage to Valuable Furniture and Woodwork

Among the numerous cases of injury to imported furniture and woodwork from shrinkage that have occurred in this country, the following might be cited as typical. The directors' room of a large western railroad company in a Chicago office building had been furnished with a large imported Chinese table made of teakwood inlaid with ivory and elaborately carved. The outer edge of the table top was constructed of four solid wood members, mitered at the corners, the inner portion of the top consisting of other pieces of solid wood separated from the outer framework by an inlaid ivory design. After this valuable table had been subjected to one winter of dry, steam-heated air, the wood members of the top shrunk sufficiently to cause the mitered joints at the corners to open up in a V-shaped crack and to cause a noticeable crack between the outer framework and the interior portion of the table, causing the inlaid work to separate and loosen. The inner boards of the top also developed cracks in the joints.

Another instance occurred in Washington, D. C. An enthusiastic collector of rare and beautiful examples of old furniture had gradually accumulated a large collection of pieces picked up in European mansions and castles. These were kept stored in a Washington warehouse and remained in good condition while in storage because the warehouse temperatures during the heating season were considerably lower than living room temperatures and humidities correspondingly higher. Some two years ago, a residence was completed and furnished with these treasures.

One can imagine the owner's dismay during his first winter in the new home when he found that the dry winter atmosphere was drying his prize pieces to the point where joints were opening up, cupboard doors and drawers were getting loose, panels were shrinking enough to expose interior wood around the edges, and certain parts were showing a tendency to twist and warp. Realizing the cause of the trouble, this owner promptly installed a small air conditioning plant and has eliminated the damage to his furniture by maintaining winter humidities of at least 40 per cent. Incidentally, he has found that these higher humidities make the house comfortable at lower temperatures and also prevent the shrinkage of floors and woodwork as well as furniture.

Preparation of Lumber

Manufacturers of furniture and interior trim in this country have learned to avoid much of this shrinkage trouble by kiln-drying their lumber to a low moisture content—usually from 4 to 6 per cent of the dry weight—before fabrication. The best practice is to store this dry lumber in heated store-rooms until it is used, in order to prevent it from re-absorbing moisture from the air, since average humidities in unheated storage will cause a regain up to from 10 to 14 per cent over a period of several months. Articles of furniture and woodwork made from lumber in such a condition are very apt to develop shrinkage troubles when used in heated buildings in the colder sections of the United States. Manufacturers having wide-spread distribution try, as a rule, to use lumber that is dry enough to meet the needs of heated interiors in cold climates.

In this attempt to avoid shrinkage troubles, however, it is quite possible to use lumber that is so dry that it will give difficulty from swelling. Sticking drawer fronts, bulging and sticking doors, warped tops, and buckled floors are some of the annoying results of swelling caused by an excessive absorption of moisture. It is true that proper design will accommodate practically all of the swelling that is apt to occur under normal conditions of use, even in the warm, humid summer atmosphere. Unusually high humidities are apt to occur occasionally, however, which may cause trouble from swelling, and it is just as well to avoid the risk of such damage by avoiding the use of over-dry lumber.

The figures in Table 1 will serve as a reliable guide to the proper range in moisture content of lumber used for furniture and other interior woodwork. Obviously, the lumber should have a moisture content more or less mid-way between the winter minimum and the summer maximum. Since damage from shrinkage is apt to be somewhat more serious than that from swelling, the optimum condition would be below rather than above the mean between the two extremes. Taking the figures for Madison, Wis., as typical of the colder sections, with a variation from 6.0 per cent to 10.5 per cent, it would appear that lumber containing from 7 to 8 per cent would give the least trouble from shrinkage and swelling under average conditions of use.

In practice, it is advantageous to dry the lumber to a cross-sectional average of from 5 to 6 per cent in which the surface might be as low as 4 per cent and the extreme center as high as 7 per cent. Surface regain will then occur during the normal period of storage and fabrication, except in extremely cold weather, sufficient to bring the cross-sectional average to between 7 and 8 per cent and uniform throughout. Control of humidity in factory and store-rooms is needed only to the extent of preventing the stock from regaining much above 8 per cent.

Equilibrium Moisture of Native Woods

The balance between atmospheric moisture and mois-

TABLE 2—EQUILIBRIUM MOISTURE CONTENT OF FOUR NATIVE HARDWOODS

SPECIES OF WOOD	PER CENT RELATIVE HUMIDITY (AT 70 F.)					
	20	35	50	65	80	95
White Oak	4.5	7.0	9.5	12.6	17.5	26.5
Black Walnut	4.8	7.0	9.4	12.3	16.7	24.4
Yellow Birch	4.2	6.5	9.2	12.4	17.0	26.0
Ash	4.3	6.7	9.7	13.2	18.0	25.2

ture in wood for any given temperature and humidity has been shown by the *U. S. Forest Products Laboratory* to be practically the same for the four species of native cabinet woods included in the test. The equilibrium moisture content of these four species at a dry-bulb temperature of approximately 70 F and relative humidities from 20 to 95 per cent are shown in Table 2, the figures and data being taken from Technical Note No. F-15 published by the *Forest Products Laboratory*.

Based on research conducted with several commercial species of softwoods and hardwoods, all of which have been found to respond in approximately the same degree to atmospheric moisture changes, the *Forest Products Laboratory* has prepared a chart, still subject to minor revision and correction, showing tentatively the equilibrium moisture content of wood over a wide range of air temperatures and humidities. This chart was published in 1928 by the *National Committee on Wood Utilization* of the U. S. Department of Commerce, in the Distributor's Edition of their bulletin entitled The Seasoning, Handling, and Care of Lumber. As a guide to engineers interested in the effect of atmospheric conditions on the moisture in wood, a portion of the data contained in this chart has been reduced by the writer to tabular form for temperatures from 50 to 120 F and for wet-bulb depressions from 4 to 30 deg as shown in Table 3.

TABLE 3—EQUILIBRIUM MOISTURE CONTENT OF WOOD FOR VARIOUS AIR TEMPERATURES AND WET-BULB DEPRESSIONS APT TO BE ENCOUNTERED IN AIR-CONDITIONING WORK (FROM DATA COLLECTED BY *Forest Products Laboratory*)

Wet-Bulb Depression Deg F.)	Per Cent Moisture Content (In Terms of Oven-Dry Weight) Dry-Bulb Temperature (Deg F.)							
	50	60	70	80	90	100	110	120
4	15.8	16.7	17.4	17.9	18.2	18.3	18.4	18.5
5	14.0	14.9	15.7	16.2	16.5	16.7	16.8	16.9
6	12.5	13.5	14.3	14.8	15.2	15.4	15.5	15.6
7	11.2	12.3	13.2	13.7	14.1	14.3	14.4	14.5
8	10.1	11.3	12.2	12.8	13.2	13.4	13.5	13.6
9	9.1	10.3	11.3	11.9	12.4	12.6	12.8	12.9
10	8.1	9.4	10.4	11.1	11.6	11.9	12.1	12.3
11	7.2	8.6	9.6	10.3	10.9	11.2	11.5	11.7
12	6.4	7.8	8.8	9.6	10.2	10.6	10.9	11.1
13	5.6	7.1	8.1	8.9	9.6	10.0	10.3	10.6
14	4.8	6.4	7.4	8.3	9.0	9.4	9.8	10.1
15		5.8	6.8	7.7	8.5	8.9	9.3	9.6
16		5.2	6.2	7.2	8.0	8.4	8.9	9.2
17		4.7	5.7	6.7	7.5	8.0	8.5	8.8
18			5.2	6.3	7.1	7.6	8.1	8.4
19			4.8	5.9	6.7	7.2	7.7	8.0
20				5.5	6.3	6.8	7.3	7.6
21				5.1	5.9	6.5	7.0	7.3
22				4.7	5.6	6.2	6.7	7.0
23					5.3	5.9	6.4	6.7
24					5.0	5.6	6.1	6.4
25					4.7	5.3	5.8	6.1
26						5.0	5.5	5.8
27						4.7	5.2	5.5
28							4.9	5.2
29							4.7	5.0
30								4.8

The figures in Tables 1, 2, and 3 represent averages. Individual pieces of wood will vary as much as 2 per cent from these averages, due to the characteristics of the particular piece of wood concerned and slight variations in the atmospheric conditions to which each piece is exposed. For example, wood close to a window is apt to have a higher moisture content than that close to an interior wall; also samples exposed to direct radiation of a radiator or heating element will be somewhat drier than wood not so exposed.

The data summarized in Table 1 are of interest from a heating standpoint as the average maximum and minimum figures are the composite result of climatic conditions of the city concerned as modified by the methods of heating used in that locality. For example, it was found that in the mild climate of Portland, Oregon, heat was maintained for a portion of each day for nearly 10 months of the year; yet the total hours of heat were only about 4,400. At Madison, heat is used nearly twice as many hours in the season, yet the heating season lasts only about 8 months. The comparatively low average moisture content and small variation between seasons at Portland can be accounted for by the fact that some artificial heat is needed almost every day during the cool evenings with the exception of about two months in midsummer when the atmospheric humidity is naturally low. In Portland, therefore, there is much less probability that furniture and woodwork in heated buildings will swell or shrink enough to do harm than in a climate such as Madison, with its lack of artificial heat and high humidity in the summer time and its continuous heat combined with the low dew-point characteristic of cold outdoor air in the winter time.

Condensation on Interior Building Surfaces

Another difficulty encountered in the colder climates of the central and eastern parts of the United States is the condensation that is liable to occur if an attempt is made to maintain a humidity sufficiently high to prevent the harmful shrinkage of furniture and woodwork. If the interior air contains very much moisture, a low outside temperature will cause excessive condensation on the inside of the windows unless these are protected by tight storm-sash. Condensation is apt to occur on walls of average heat transmission if humidities much above 40 per cent are present when the outside temperature is zero or below.

It is evident, then, that the maximum humidity which it is practicable to maintain in heated buildings in cold weather is directly dependent upon the out-door temperature. The lower the out-door temperature, the lower must be the interior humidity, even if means are available to humidify the interior air. In the case of museums, housed in monumental buildings with very thick walls, this will not be as true as in ordinary dwelling houses, but even in museums care must be exercised to prevent the humidity from reaching a point where condensation will occur. Fortunately extremely cold weather is usually of short duration and the use of a higher humidity between cold spells will usually be sufficient to prevent any harmful shrinkage in furniture and woodwork that is protected against rapid moisture changes by paint or varnish.

Even in the coldest weather it is usually possible to maintain a relative humidity of at least 35 per cent. At 70 F, this will ultimately dry the wood to a moisture content of 7 per cent if continued for several weeks.

The removal of the last 1 per cent is so slow, however, in varnished or painted furniture or woodwork, that such articles are not apt to dry much below 8 per cent during the duration of the usual period of cold weather. By raising the humidity to 40 or 50 per cent during the mild periods between cold snaps, the effect of the dryer periods is more or less compensated by intermediate periods of re-absorption which will tend to prevent the wood in a humidified building from drying below 8 per cent even in a cold climate. This would not be true, however, in buildings not provided with adequate arrangements for adding moisture to the interior air as needed.

The problem of preventing excessive absorption and swelling in the summer is not so simple, as this is only possible where facilities are available for dehumidification of the interior air. Where such facilities are available, as in museums, department stores, and office buildings, a relative humidity averaging not higher than 60 per cent and preferably about 50 per cent will keep woodwork in excellent condition and confine swelling to a negligible amount. Fortunately, as pointed out before, a normal amount of swelling is provided for in the design of most furniture and woodwork so that the probability of damage during exposure to summer humidities is slight, particularly if these articles are not allowed to become excessively dry during the winter heating season.

Components of Air in Relation to Animal Life

Oxygen, since the time of Lavoisier, has been considered the vital component of the air. The 79 per cent inert part has had little use assigned to it. Popular opinion had stated that animal life would be more efficient if these inert gases were replaced by oxygen.

Experiments Conducted

Carefully conducted experiments, covering a period of eight years, have been carried out by the writer and his assistants. A glass jar of five-gallon capacity was used as an air-tight container for the larger animals and a gallon bottle for the smaller ones. The gas was introduced through holes in a stopper fitting the larger mouth of the container, entering at the top and passing out near the bottom. The natural feed for the different animals and water were kept before them constantly. A small container of sodium hydroxide was placed at the bottom of the jar to take up any excess of carbon dioxide. The outflow of gas from the glass jar was passed through lime water to show that carbon dioxide was given off and the speed of the escaping gas.

The gas in the jar was frequently tested quantitatively and the analysis showed that it never had an excess of carbon dioxide over that of ordinary atmosphere. A very accurate record was kept of the rate of breathing and the general appearance of the animals. Chemically pure oxygen was used.

Animals can not live in an atmosphere alone of oxygen, nitrogen, carbon dioxide, helium or argon, according to the results obtained. In a series of thirty experiments it was found that small animals such as mice, rats, pigeons, cats, guinea-pigs, snakes, monkeys, etc., can live in a medium of air under control, but in pure oxygen under the same conditions they will die within from two to five days. In only one case did any of the animals live over a week in oxygen—the snake lived four weeks—while in a current of air we had the different animals under control from one to three weeks without any signs of ailments. With the representative varieties of animal life it was found that in an atmosphere of pure oxygen, with other conditions normal, without a single exception every one would die in oxygen and none in air.

The breathing of the animals was usually found to increase gradually at first in the oxygen atmosphere, but later they appeared to breathe with more difficulty and more slowly until they died. From the appearance of their actions they did not seem to suffer much from pain.

Atmosphere of Nitrogen and Oxygen

Natural air contains 21 per cent oxygen, 78 per cent nitrogen and 1 per cent mixture of argon, neon, krypton, xenon, helium and carbon dioxide. An atmosphere which contained 21 per cent of oxygen and 79 per cent of nitrogen by volume was prepared, leaving out the rare gases. The experiment was repeated six times. Blank tests with normal atmosphere were under simultaneous observation. White mice were used as experimental subjects. No difference in the physiological effects was noted because of insufficient atmosphere supply.

This series of experiments led to the conclusion that the rare air gases such as argon, helium, neon and carbon dioxide are vital for normal respiration. Without these rare gases included with the normal amount of nitrogen and oxygen, life would not exist longer than ten days. The rare gases seem to play a part in normal life equally as important as oxygen.

By increasing the mixture of oxygen to 25 per cent and decreasing the nitrogen to 75 per cent the animals were under control for three weeks without any signs of ailment. The experiments were continued by using mixtures as follows: oxygen 30 per cent and nitrogen 70 per cent; oxygen 40 per cent and nitrogen 60 per cent; oxygen 50 per cent and nitrogen 50 per cent; oxygen 60 per cent and nitrogen 40 per cent, when the animals appeared to be normal and in a few cases better than in the normal air. By making a mixture of oxygen 70 per cent and nitrogen 30 per cent they seemed abnormal after being in this atmosphere for about a week. In an atmosphere of 80 per cent oxygen and 20 per cent nitrogen they would die in nine days, and they would live but seven days in an atmosphere of 90 per cent oxygen and 10 per cent nitrogen.

In an atmosphere of pure nitrogen alone the animals would live but six minutes; in argon alone, three minutes; in pure oxygen, from two to six days, and in hydrogen thirty-seven minutes.

From these experiments with pure oxygen and with the different mixtures of oxygen and other gases it seems that one might be able to find a mathematical curve between the mixture of gases and the time of living with animal life.

In a number of cases it was found that artificial atmospheres could be prepared that supported life in white mice more effectively than the normal air we breathe every day.

[1] From an article by J. W. Hershberg of McPherson College which appeared in a recent issue of *Science*.

Air Pollution from the Engineer's Standpoint

By H. B. Meller[1], Pittsburgh, Pa.
NON-MEMBER

SMOKE abatement is the term generally applied to efforts to reduce the volume of black smoke emitted from chimneys as a result of incomplete or improper combustion of fuel. Entirely aside from the damage to health and property resulting from the pollution of city air by the solids and gases issuing from chimneys, inefficiency in the burning of fuel is a direct money loss. It would be no exaggeration to say that 20 per cent of the present fuel bill of this country is wasted by preventable inefficiency.

The smoke nuisance is as old as the use of coal, and agitation against it has been in proportion to the discomfort caused. At present 125 cities in the United States, over 30,000 in population, have anti-smoke ordinances. Special surveys of conditions have been made in New York, Chicago, St. Louis, Salt Lake City, Boston, Baltimore, Pittsburgh and other cities.

Origin and Composition of Smoke

Fuels that contain little volatile matter, such as anthracite and coke, will burn without appreciable visible smoke, although ash is carried off in proportion to the draft. On the other hand, semi-bituminous coals, to a degree, and bituminous coals high in volatile matter, may be bad smoke producers, as may liquid fuels under some conditions. As a rule, the amount of volatile matter may be considered an indication of the smoke-producing nature of coal. But volatile matter itself varies in composition from that containing gases and compounds that are not difficult of combustion in an ordinary furnace without the production of visible smoke, to that which can be burned without producing dense smoke only in carefully constructed and operated furnaces.

Combustion and Its Products

Theoretically, the process of combustion is simple, being a chemical union of the combustible material of a fuel with oxygen from air, the combination resulting in the development of heat. In practice, however, many difficulties are encountered which tend to complicate the process, and it is in overcoming them that care is required in the construction and operation of furnaces. The number and nature of the difficulties vary considerably with the composition and fineness of the fuel, the type of furnace, the method of firing, the supply of draft, the amount and composition of impurities in the fuel, and the variable demands for heat or power. Briefly stated, the stages of combustion are:

1. Absorption of heat.
2. Distillation and combustion of the volatile matter.
3. Combustion of the remaining or carbonaceous part of the fuel.

The difficult part of the process is to secure complete combustion of the products evolved in the second stage, before they strike any cooling surfaces that will reduce their temperature below the ignition point. The requirements of complete combustion are:

1. Air in sufficient quantities must be admitted at the proper time and place.
2. Thorough mixture of the air with the gases evolved, which involves an element of time, requiring sufficient space in the combustion chamber.
3. The temperature of the gases must be maintained above their kindling point until combustion is complete.

If these conditions are met, the products of combustion will be carbon dioxide and water vapor, plus sulphur dioxide (SO_2), sulphur trioxide (SO_3), a small amount of hydrogen sulphide (H_2S), various sulphur-containing organic compounds, and in addition, such solid particles of ash and carbon as may be taken out by the draft. Only a haze will be visible coming from the stack. On the other hand, incomplete combustion will result in the production of visible smoke in smaller or larger quantities.

In installations where the temperature and draft are comparatively low, and the methods of firing irregular—as in the domestic furnace—the soot contains a comparatively large percentage of combustible matter (carbon, hydrogen and tar) with a small percentage of ash. Where the furnace temperature and draft are comparatively high, small amounts of coal being fired at relatively short intervals, the percentage of combustible is much lower, but larger amounts of ash are carried off.

In industrial cities, the sootfall amounts to hundreds of tons per square mile per year. This deposit may contain as much as several per cent of tarry matter and 20 to 30 per cent of fixed carbon.

Effects of Smoke[2]

In a consideration of effects, there must be taken into account all of the products of combustion—not merely visible smoke.

Meteorological Aspects of the Problem

While the elementary gases—nitrogen, hydrogen, oxygen, and the gases of the argon group—are practically fixed in amount with respect to one another at any given level, the compound gases, such as water vapor, ammonia, ozone, and carbon dioxide gas are varying constantly, not only with respect to the atmospheric conditions, such as temperature, pressure, and humidity, but also with

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[2] The information presented in this section and also in the next two sections has been gleaned from the results of studies made under the auspices of Mellon Institute during the period 1911-14 and in 1923 and 1930.

respect to place. This is especially true of gases generated in the process of combustion, which may be almost unknown in thinly inhabited districts, but which must be taken into account in the atmosphere of large cities.

Suspended Matter. The gases of the atmosphere hold in suspension considerable quantities of solid and liquid particles. The latter consist principally of condensed water vapor, forming fogs and clouds, which may hold in solution substances of various kinds, including some acids. The solid particles are meteoric dust, finely divided mineral matter or soil from the surface of the earth, pollen from plants, microscopic organisms such as bacteria and moulds, and the residues of combustion.

Dust Layers in the Atmosphere. There exist in the atmosphere three well-defined dust layers, of which the lowest, less than a mile in thickness, is of primary importance, because in it are carried on nearly all human activities. This dust layer consists of comparatively coarse particles caught up by the turbulent surface wind. Its density depends upon the relation between the rate of supply and the rapidity with which the particles can be carried away or distributed throughout the atmosphere. The least dust is found in sparsely inhabited regions covered with dense vegetation. In large cities, especially where bituminous coal is burned, the discharge from numerous chimneys produces the densest dust or smoke layer. Diurnal convection carries fine dust to a height of nearly three miles, and the convective action of storms carries it to the base of the stratosphere—the portion of the atmosphere lying above the region of convection—at a height of about seven miles.

The *effects of atmospheric impurities upon meteorological conditions* depend not only upon the size of cities and the rate of discharge of their impurities into their atmospheres, but also upon the rate at which the vitiated atmosphere is carried away. They vary, therefore, with geographical position, season, average wind velocities, and topography.

Smoke aids in the formation and prolongation of fogs. Condensation of atmospheric moisture takes place only when the saturation temperature has been reached, and then only upon free surfaces, such as the surfaces of suspended dust particles. In the city, fogs become mixed with smoke to such an extent that their color is frequently changed from white to brown, or even black, and their density is so increased that they are almost opaque to sunlight. And, of course, the lighter the wind the greater the density. Then, too, the absorption by soot particles of moisture from the fog so increases the weight of such particles that they quickly settle to the lower atmospheric levels. Oily or tarry substances also form a coating on the fog particles and retard evaporation. Also, in the presence of sulphuric acid, evaporation of the fog particles is retarded. Furthermore, the increased opacity of city fogs prevents penetration of heat rays from the sun to any considerable depth, so that fogs persist materially longer in a large smoky city than in the suburbs, and still longer than in the country.

It is obvious that the observed hours of sunshine are less in large cities than in the suburbs or in the country. However, the sunlight which does filter through is deficient in rays of the shorter wave-lengths, thus reducing materially, and at times cutting off entirely, the beneficial ultraviolet radiation.

Effects of Smoke on Stone

The products of combustion of fuels that are injurious to stone may be divided, roughly, into two classes: (1) those that soil and render the buildings unsightly, that is, carbon, tar, ash and their various combinations; and (2) those that corrode and in general aid in the destruction and weathering, that is, sulphuric acid (H_2SO_4), and sulphurous acid (H_2SO_3), hydrogen sulphide (H_2S), hydrochloric acid (HCl), ammonia, the organic acids, etc.

The action of carbon and ash, when not associated with tar, is not extremely objectionable, as the simple process of brushing will remove either. When, however, they are associated with tar, especially in the case of soot, they produce the most objectionable kind of dirt. The tar causes the soot to adhere firmly to any surface with which it comes in contact, literally covering the object with a coating of black paint and penetrating into the porous structure. This coat is not readily removed, because it has adhesive properties and also because it is insoluble in water. Drastic measures, such as the use of solvents, scouring, or both, frequently are necessary. Steam cleaning has been used recently for this purpose.

Of the corroding agents, sulphuric acid is the most important. Sulphurous acid, while of itself not particularly active, is changed rapidly by oxidation in the air to the far more corrosive and injurious sulphuric acid. Hydrochloric acid is of less importance; ammonia and hydrogen sulphide are practically without corrosive action on stone, but contribute to the corrosion of bronze and other exposed metals.

It might not seem that the amount of acid coming from the chimneys of a large city would be sufficient to do much harm. However, coal as fired contains an average of at least one per cent sulphur, or 20 lb. per ton of coal, and, say, 75 per cent of this constituent, or 15 lb. per ton of coal burned, escapes into the atmosphere. If, for example, this is considered as sulphuric acid, it would be equivalent to 46 lb., which, if it all were allowed to act on limestone ($CaCO_3$), would destroy 47 lb. and produce about 80 lb. of gypsum ($CaSO_4 \cdot 2H_2O$).

Part of the acid as it leaves the chimney is occluded in the soot and part goes out in the form of gas with the other products of combustion. That which escapes with the flue gas is dissolved by rain and will corrode any material with which it comes in contact and upon which it can act, but it is soon washed off. That occluded in the soot is more injurious, as the tar causes firm adherence to anything with which the soot may come in contact. This acid is not readily washed away by rain and in all probability, if it is adhering to corrodible material, the action is complete.

Stones that do not contain the carbonates of calcium and magnesium—granite, gneiss, and sandstones in which the grains of sand are cemented by substances other than the carbonates—are but little affected by the corroding agents derived from combustion. They are, however, soiled by soot, and the necessary cleaning by wire brush and detergent chemicals, a sandblast, or other drastic method, is not only costly, but injures the stone itself. All rock contains water, the greater the percent-

age of porosity, the more water. After removal from the quarry, this contained water, as well as any which is absorbed by the rock after quarrying and which becomes saturated with the various substances of which the rock is composed, gradually comes to the surface and is evaporated, depositing the dissolved minerals in the form of a hard, compact crust. The removal of this protective crust hastens the weathering of the stone. Furthermore, the stone is soon as dirty as before.

The action of sulphuric acid on stones containing larger or smaller amounts of the carbonates of calcium and magnesium—limestone, dolomite, dolomitic limestone, and sandstones with a calcareous cementing material—is, for the most part, the action of this acid on these carbonates. This chemical action involves a change in volume. Still more important than the volume change is the pressure developed by the sulphate crystals growing in definite oriented directions. This is apt to occur in all kinds of stones; even granites are not exempt. The stone becomes more porous, loses its cohesion, and disintegrates with much greater ease under the action of the weather.

Mortar, because of its rather porous structure, and because it is in process of chemical change for some time after it is placed in the wall, is particularly subject to the action of the atmospheric acids. This will be evident upon examination of the mortar in old buildings.

What has been said for stone applies equally to concrete. The griming of the surface is just as serious, and the action of the sulphuric acid is at least as detrimental, if not worse, for it reacts upon the aluminate of the cement, forming a complex substance the volume of which is three times that of the original aluminate. Moreover, both this complicated aluminate and the gypsum formed by interaction with the lime in the cement grow under favorable conditions into crystals of appreciable size, which, acting like millions of tiny jacks, produce a tremendous pressure in the aggregate.

Effects of Smoke on Metals

Soot as a Coating. Soot that does not contain injurious constituents may, in fact, act as a protective coating. However, this coating is not uniform; and where metallic surfaces are intended to be of decorative value, the effect is spoiled, if not entirely destroyed, by the mottled soiling. The remedy in such case is simple—wipe off the dust.

When the surface is covered by soot containing tar, or soot and tar separately, oftentimes scouring is necessary to clean the surface, but this results in injury to the metal through abrasion. If the soot is allowed to remain, any intended decorative effect is destroyed in this case also.

Effect of Hydrogen Sulphide and Ammonia. These two gases are to be considered as definite sources of corrosion of metal work and as the cause of the staining of certain types of paints and of bright metal surfaces. Of the two, hydrogen sulphide is the more active and troublesome, since the metallic sulphides which are formed first are easily oxidized to sulphates in moist air, and these salts accelerate further corrosion. It should be emphasized that under ordinary conditions the quantities of hydrogen sulphide and ammonia in the atmosphere are so slight that they do not appear to be major causes of corrosion. Because of their possible catalytic action, however, they are not to be disregarded.

Sulphur Acid. In estimating the possible damage to a municipality from the effects of the sulphur acids, it must be borne in mind that not only sulphur from fuel burned in that municipality must be considered, but also that which originates from other communities in the same district, much of which is brought in by air currents, just as a considerable amount of that from the city is carried out, to do its damage elsewhere.

Finely divided carbon has the power of occlusion to a high degree, a fact which makes possible the retention of some sulphur acids. Since corrosion occurs only in the presence of moisture, soot also aids corrosion by retaining moisture. Iron oxide has this power of occlusion, although to a less degree than does carbon; and when this oxide is formed, destruction of the iron is hastened by absorption of acid from the air.

When soot containing tar comes in contact with a metallic surface, the tar causes it to adhere more or less firmly. Thus the occluded acids, principally sulphuric and sulphurous, are brought into intimate contact with the metal, affording a much better opportunity for corrosion to take place and more quickly than if the same amount of acid dissolved in rain water were to come in contact with the metal.

The rapidity and completeness of corrosion by this combination are aided further by the fact that any free carbon that the soot may contain is electro-negative, while the metals are electro-positive. Thus galvanic action takes place readily in the presence of the acids and water.

Corrosion of the Metals. The destruction of iron is most noticeable, for it is the metal in most common use, and it is more readily corroded than the majority of metals. Iron remains unchanged in dry air and in dry, inert gases. However, when the air is moist, and more especially when it contains acid vapors, the iron rusts (oxidizes), forming hydrated oxide of iron. It is attacked by dilute sulphuric and hydrochloric acids with the liberation of hydrogen. Action of any of the corrosive agents is hastened greatly by any arrangement of substances which makes electrolytic action possible. The corrosion of either protected or unprotected iron work is much more rapid in city air containing the sulphur acids and other corroding agents than in the country. Investigations of iron alloys show that small quantities of some elements, when alloyed with the iron, materially reduce the rapidity of corrosion by the various corroding agents.

Zinc is acted upon readily by most dilute acids, the mechanism of corrosion being similar to that of iron. In moist air, a thin protective coating of a white, basic carbonate is formed; this coating, being soluble in sulphuric acid, is destroyed readily when the air carries acid vapors. Iron protected with a coating of zinc corrodes more rapidly, once the coating is broken, than either metal alone, because of electrolytic action.

Tin is little affected by the acid-containing air of smoky cities. However, where it is used as a protective coating for iron, corrosion is hastened by galvanic action, especially when part of the coating is worn away, exposing the iron as well as the tin. Where tin plates are

soldered together and the soldering is not perfectly done, corrosion is aided greatly by electrolytic action.

Copper is acted upon very slightly by dilute hydrochloric and sulphuric acids. In moist air accompanied by acids, it becomes coated with verdegris. Both copper and brass are particularly sensitive to the action of hydrogen sulphide. Copper and many of its alloys are attacked readily by both ammonia and nitric acid, which are present always in the air, although in small quantities.

Lead is not corroded appreciably by air, although its surface dulls on exposure, owing to the formation of oxide. Dilute hydrochloric and sulphuric acids have little effect on the metal, and that effect is beneficial in a way, especially in the case of sulphuric acid, as lead sulphate is quite insoluble.

Aluminum is unaffected by corrosion in a smoky atmosphere. Exposure of this metal under such conditions for as long as twenty years showed no appreciable deterioration. The surface accumulation of dirt may readily be washed off.

Effects of Smoke on Outside Painting

Particles of carbon deposited upon paint apparently tend to increase the life of the coating, since the ultraviolet light which affects the films is absorbed at the surface.

Sulphur dioxide is particularly harmful to a paint film when high percentages of carbon dioxide are present and when high humidity conditions exist. Paint films applied under such conditions nearly always dry with tacky surfaces that are subject to contamination by atmospheric carbon and dust, reducing the protective efficiency.

Paint darkened when applied to test fences, erected in different localities in the United States; the tarry matter from deposition of soot seemed to be thoroughly incorporated in the film. Paint applied over a soot-coated surface was attacked by the soot beneath as well as by that deposited on the exposed surface. Frequent washing of paint coatings is necessary, and paint must be renewed in much less time in a smoky atmosphere than in one comparatively free from smoke.

Effects of Smoke on the Interior of Buildings

Fine soot, as an impalpable powder, will go anywhere and everywhere that air does, and the tarry matter with it causes much of it to adhere firmly to any surface with which it comes in contact. Changes in atmospheric pressure produce changes in the air currents in shut-in or confined places, carrying the soot to the most unexpected corners. A common and striking example of this is the framed picture, with little dark sprays of soot along the white mats or on the picture itself, where the air currents have reached the space behind the glass.

The most noticeable damage of the soot is in impairing appearances and causing an enormous amount of extra, expensive and unnecessary work and care in keeping working and living quarters in such condition as is required by people accustomed to the common standard of living. While in the interior of buildings, damage by the sulphur acids is not so marked as in the case of material exposed to the weather, they undoubtedly cause considerable damage to delicate fabrics.

For the architect or decorator the market does not offer a paint or wall covering that is not susceptible to damage and the life of which is not shortened by soot. And the possibilities of the choice of colors for interior painting are limited appreciably. Wall paper must be cleaned more often in a smoky city; its life is much shorter than in a clean atmosphere. Lace curtains and hangings are soiled easily by soot and must be washed frequently. Soot is readily ground in on a floor rug. Altogether, the cost of upkeep of paints, decorations and furnishings is from two to five times as much as in a clean city. The cost of illumination is increased in a smoky city, not only by absorption of the light in its passage through the atmosphere, but also because of soot coating skylights, windows, lighting fixtures, etc.

Air Conditioning. For a building in which it is desired to have cleaner air than that of the outside—as for dry cleaning, laundering, food manufacture, etc., or in a department store, office building, hospital, school, club or elsewhere—air conditioning is applicable. Incoming air may be filtered or washed or both to eliminate such solid particles as can be removed by the process and to supply cleaned air of a predetermined humidity.

Effects of Smoke on Vegetation

The general opinion that smoke injures nearby vegetation is justified, as evidenced not only by the external appearance of many of the plants, but also by their internal appearance as shown by the size of annual rings and by lesions in leaves.

Experiments have shown that, especially in the case of pines, when soot is applied in small quantities over a considerable period of time, measurable injury follows. There is some clogging of stomata by carbon in the soot; but the injury done by the soot of smoke is due, probably, chiefly to the accompanying ash, tar and gases. Sulphur dioxide, when present, is absorbed by the leaves and forms sulphuric or sulphurous acid, which are toxic in the tissues of the leaves. Ordinary field and garden crops do not thrive in a very acid soil. Smoke is, therefore, injurious to vegetation.

Psychological Aspects of the Smoke Problem

The smoke palls of industrial centers have both direct and indirect effects upon mental well-being.

Direct Influences. The constant inhalation of poison-laden air probably results in a gradual process of absorption by the human system of the poisonous products of combustion. This insensible intake may not give rise to any definitely recognizable acute disorder or specific disability. But the process of slow poisoning may eat away, insidiously, like a mild canker, at vital tissues, making it impossible for body and brain to function at their points of maximal efficiency.

Indirect Effects. The indirect effects of smoke upon the human organism are traceable to the various meteorological states due to the products of combustion which get into the atmosphere and which, in turn, directly influence the body and mind. These are, particularly, sunshine, clouds, humidity, fogs, temperature, electrical potential and luminosity. It has already been shown that smoke aids in the formation and prolongation of fogs, that it reduces the amount of sunshine, particularly in the shorter wave-lengths considered so beneficial, decreases the limit of visibility and affects the diurnal temperature.

The action of these smoke-induced conditions upon

the human being may be considered largely in terms of sunshine dynamics. On the one hand are the influences of positive states of sunshine: brightness, luminosity, warmth, dryness, the presence of the infrared, visible and ultraviolet rays, and high electrical potential. On the other hand are the effects of the negative states: gloom, darkness, cloudiness, fogginess, rain, moisture, cold, and low electrical potential.

On clear, dry, sunny days, persons are more active, aggressive and enterprising. On the other hand, dark, humid days are devitalizing, and therefore lead to inaction. Depleted vitality and nervous exhaustion are inhibitory of action.

Hygienic Aspects

In hygiene, the influences of smoke are both direct and indirect—direct from inhalation and indirect because of meteorological states resulting from atmospheric impurities. The psychological and hygienic effects of smoke are so closely related that it is impossible to draw clearly any line of demarcation. Bodily states normally influence mental states, and mental states, in turn, normally influence bodily processes, particularly the functions of the glandular, circulatory, sexual and neural systems.

Inhalation of Dust. When it is remembered that the average adult breathes about 30 cu. in. of air in each inhalation—equivalent to approximately 37½ lb of air per day, or about seven times the weight of food and water consumed—it does not seem an exaggeration to say that more persons are devitalized, disabled and poisoned by the impurities contained in smoke-polluted air than by the noxious ingredients in food and water. Not only do these air-borne impurities irritate the sensitive membranes of the eyes, nose, throat and lungs, and thus aggravate or cause diseases of these organs, or produce collapse of their sensitive tissues, or increase their susceptibility to acute respiratory diseases; but poisonous compounds also enter the gastro-intestinal tract and may cause nausea, vomiting, diarrhea and systemic poisoning.

A part of the human waste caused by smoke-polluted air certainly is due to the irritation caused by the solids. The functional efficiency of the visual, naso-pharyngeal, pulmonary, gastro-intestinal and neural mechanisms may be more or less disabled by such solid particles. But it is likewise presumptively possible that irritating, acrid soot particles and poisonous smoke compounds may, by slow, insidious action, become factors in depleting potential reserve, leaving open the way for sickness, or even premature decay and untimely death.

Relation of Smoke to Diseases of the Respiratory Tract. It is not surprising to find that the burden of proof has been sought in the relation of smoke to diseases of the respiratory organs, because the lung tissue is necessarily first invaded by the smoke content of the air inhaled. Accordingly, the majority of observers have based their studies upon the incidence of lung disease in smoky industrial cities.

Pulmonary anthracosis (not in coal miners) is distinctly an urban disease and is proportionate to the smoke content of the air. Although small quantities of carbon deposit in the lung may remain without harm, yet the quantity accumulating in the dweller of one of the larger cities has an accompanying greater or less fibrosis, impairing the elasticity as well as altering the functional capacity of the organ.

In tuberculosis and granulomatous conditions in which the reactions are centered chiefly in focal lesions of the tissues, the anthracotic condition is either entirely passive, or is active in assisting healing, in that it is an additional stimulus to fibrosis and encapsulation, and in that it aids in the localization of the process through the obliteration of the lymph spaces. In acute inflammatory conditions where the lymphatics are important for proper resolution, anthracosis becomes seriously detrimental, because of the obliteration of these spaces.

Pneumonia, on the other hand, is a catarrhal condition, and a predisposition for it may be prepared by the irritation of the mucous membranes with foreign substances. The survey of the Mellon Institute (1912-14) showed a strikingly close relationship between the pneumonia death rate and the smoke content of the air as charted by wards.

Effects of Smoke-Induced Weather States. The amount of blood and the percentage of hemoglobin are increased by sunlight and decreased by darkness.

Smoke intercepts the sunrays of the shorter wavelengths. These shorter waves, in addition to their effect in restricting bacterial growth, stimulate the powers of resistance to bacterial infection by their action on certain fatty substances in the skin.

Rickets, and other disturbances of the metabolism of lime salts very important to health, result when the short or ultraviolet rays of the sun are excluded from the body. When the nutrition of the body is thus vitiated, it becomes more susceptible to bacterial infection.

Soot has a definite bactericidal action, probably due to the action of its contained germicidal acid and phenols; it does not form a favorable nidus for the collection and distribution of bacteria. On the other hand, soot, as it occurs in smoke, clouds, fogs and as a non-transparent covering for streets and buildings, protects micro-organisms from the destructive action of sunlight.

The Responsibility of the Engineer

It may be asked why so much space has been taken to describe the effects of air pollution. The answer is that the responsibility for the development and application of corrective measures is with the engineer, and he will be better able to judge what is necessary if he has a knowledge of the havoc wrought by the impurities introduced into the atmosphere from equipment which he has designed, installed or operated.

To say that power or heating equipment satisfies a local anti-smoke ordinance is begging the question, because he knows that, in the nature of things, the law must follow development. A smoke abatement enforcement officer may suggest improvements, he may take advantage of possibilities that exist, but he cannot make any regulations impossible to be met by equipment already on the market.

As scientific research demonstrates how to use fuel more economically, and as *smokeless fuel* (especially coke and gas) and electric power come into more general employment, advancement in effective smoke abatement will become more rapid. However, it has seemed to the writer that the heating and ventilating engineer has not given adequate encouragement to the development of

combustion engineering as a specialty. As is generally known, there is a dearth of combustion engineers, due to the lack of instructional facilities for their training in this country.

A great deal has been done in the matter of smoke abatement through the co-operation that exists between the engineers and local bureaus of smoke regulation. Manufacturers have listened to suggestions made. There are stokers, powdered coal burners, *smokeless* boilers, secondary air-supply devices, smoke indicators, and so on. These aim at elimination of visible smoke.

As has been shown, however, visible smoke is only a comparatively small part of the problem. There are solids that do not color the smoke stream, and noxious and obnoxious gases. To combat the evil of solids, there are various types of separators. While admitting that such devices have great merit, the fact remains that, because of expense, their application is limited.

What Must Be Done

There is already adequate engineering knowledge awaiting application, and at the proper time the engineer must introduce such combustion processes and power generating procedures as will solve as completely as possible the dust and smoke problem of the large cities. The great advances that have been made recently in the distribution of natural gas in the southern and mid-western states reveals the ability that the engineer has in solving his part of the problem when he has the raw material — fuel in this case — and support and encouragement.

In advance of the time when electricity, generated at central points or at the mine, will furnish power, heat and light, and so give us the *White City*, it is felt that the manufacture and distribution of steam by central stations for both heating and industrial processing use will also help to rid cities of smoke from small and often poorly operated plants. There are now over thirty companies in the steam business, mostly in the northern and central states.

It seems to the writer that the necessities for a hygienically clean atmosphere, and not one merely free from visible smoke, may be grouped about as follows:

1. Solids not to be discharged from stacks as at present. Similar elimination or neutralization of noxious and obnoxious gases. Once these impurities are in the air, they cannot be controlled.
2. Control of automobile exhausts, so that the present large volume of products of incomplete combustion from this source shall be eliminated.
3. Such methods of street and roof cleaning, and care of railroad rights of way as will reduce to the minimum the amount of dirt that can be picked up and carried by the wind.
4. Reducing to the minimum the bare spaces from which dirt may be picked up.

This may seem Utopian, but consider what has been done for the water and food supplies. It is the engineer's job, and the engineer is capable of doing it.

Comparative Heating Costs

It is frequently desired to obtain comparative costs of fuels and other heating media in terms of the heat actually available for heating purposes. To do so, it is necessary to take into consideration the calorific values of the fuels under consideration, the overall heating efficiences and the fuel costs. A convenient basis for comparison of various fuels is the cost per million Btu, and the following formulae may be used for obtaining comparisons on this basis:

(*a*) *Coal*

$$X = \frac{500 \times c}{C_c \times E_c}$$

where

X = cost of heating with coal in dollars per million Btu

c = cost of coal in dollars per ton

C_c = calorific value of coal, Btu per pound

E_c = overall or house efficiency for coal, expressed as a decimal

If $C_c = 13{,}000$ Btu per pound, and $E_c = 0.60$, then

$$X = \frac{500 \times c}{13{,}000 \times 0.60} = 0.064c$$

Example. If coal costs $10.00 per ton, the cost per million Btu will be $0.064 \times 10 = \$0.64$ or 64c per million Btu.

(*b*) *Oil*

$$Y = \frac{1{,}000{,}000 \times p}{C_o \times W \times E_o}$$

where

Y = cost of oil in dollars per million Btu

p = cost of oil in dollars per gallon

C_o = calorific value of oil, Btu per pound

W = weight of oil per gallon, pounds

E_o = overall or house efficiency for oil, expressed as a decimal

If $C_o \times W = 141{,}000$ and $E_o = 0.70$, then

$$Y = \frac{1{,}000{,}000 \times p}{141{,}000 \times 0.70} = 10.1p$$

Example. If oil costs 10c ($0.10) per gallon, the cost per million Btu will be $10.1 \times 0.10 = \$1.01$, or say $1.00 per million Btu.

(*c*) *Gas.*

$$Z = \frac{1000g}{C_g \times E_g}$$

where

Z = cost of heating with gas in dollars per million Btu

g = average cost of gas, including demand and commodity charges, dollars per thousand cubic feet

C_g = calorific value of gas, Btu per cubic foot

E_g = overall or house efficiency for gas, expressed as a decimal

If for manufactured gas, $C_g = 535$ and $E_g = 0.80$, then

$$Z = \frac{1000g}{535 \times 0.80} = 2.33g$$

If for natural gas, $C_g = 1000$ and $E_g = 0.80$, then

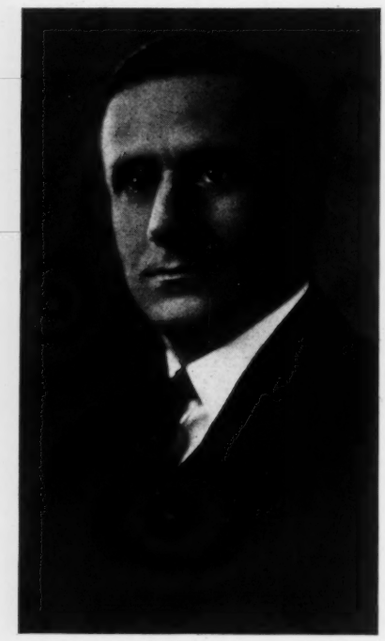
$$Z = \frac{1000g}{1000 \times 0.80} = 1.25g$$

Examples. If manufactured gas costs $1.00 per thousand cubic feet, the cost per million Btu will be $2.33. If natural gas costs $1.00 per thousand cubic feet, the cost per million Btu will be $1.25.—*P.D.C.*

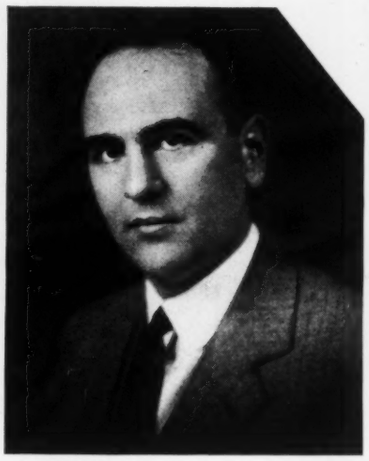
F. A. GUNTHER

R. B. STANGER

F. C. HOUGHTEN



H. LEE MOORE



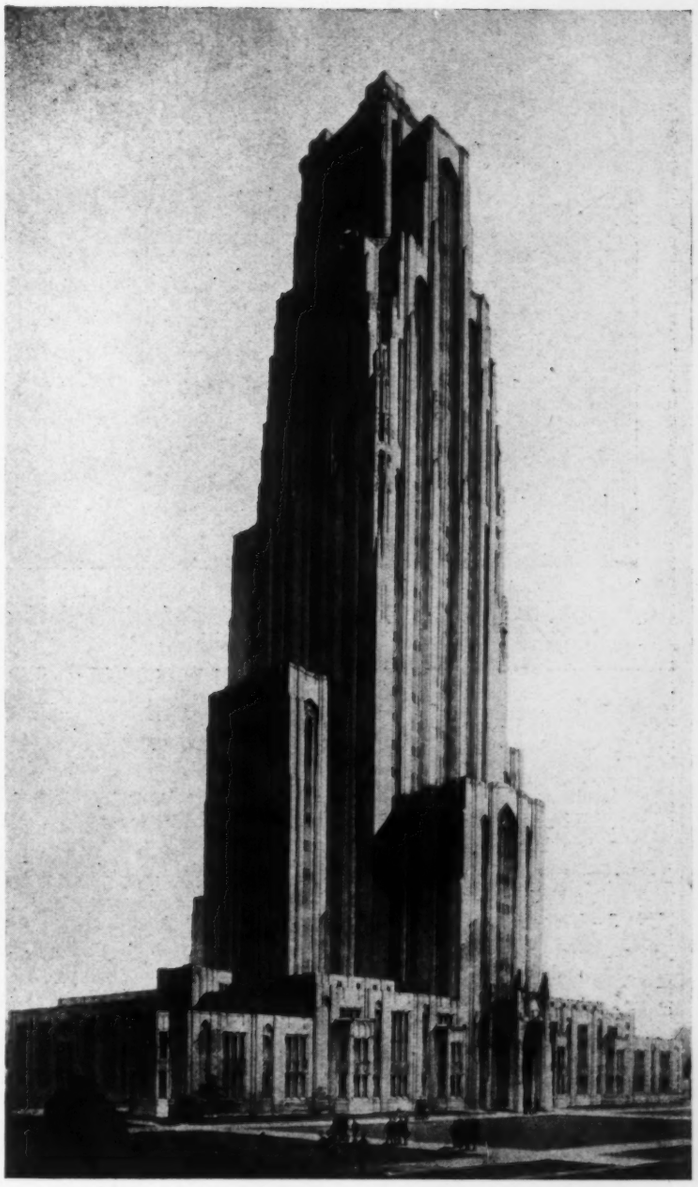
F. C. MCINTOSH

W. W. STEVENSON

J. E. MCGINNESS

H. B. ORR

Pittsburgh's Plans for 37th Annual Meeting January 26-29 Complete



THE CATHEDRAL OF LEARNING
UNIVERSITY OF PITTSBURGH

EVERY Society member has received an invitation from the Pittsburgh Chapter members to attend the 37th Annual Meeting at the William Penn Hotel, January 26 to 29, 1931.

The "Workshop of the World" offers innumerable attractions and everyone who makes the trip will recall it with pleasant memories.

Six technical sessions are to be held, the first one Monday afternoon, January 26 at 2 p. m. All sessions except the fourth on Wednesday morning will be held in the William Penn Hotel. This fourth session will open at 9:30 a. m. in the U. S. Bureau of Mines Experiment Station, 4800 Forbes St., and upon its conclusion luncheon will be served. An opportunity will then be given to the visitors to inspect the Bureau of Mines, the A. S. H. V. E. Laboratory and Carnegie Institute of Technology.

A wide variety of subjects will be discussed at the sessions and 19 papers have been selected by the Program and Publication Committees for presentation.

In addition to this list of important papers several codes will be presented, notably a Code for Testing and Rating Concealed Gravity Type Radiation and the Code for Testing Steam Heating Boilers Burning Oil Fuel. These committees were appointed earlier in the year and have accomplished a great deal in preparing these codes for submission to the Society.

With a varied technical program there will be something to interest every member at each session.

Attractions in the way of entertainment are numerous and H. Lee Moore, General Chairman of the Committee on Arrangements, has endeavored to introduce some features that are unusual and will make this 37th Annual Meeting different.

Events will be on an informal basis on Monday evening, at 9 o'clock, when the Society is invited to spend A Night in Pirate Hall (at William Penn Hotel).

Tuesday at 11:00 a. m., the ladies will be entertained at a breakfast bridge and in the evening there will be an amateur championship tournament on the miniature golf course of the William Penn Hotel and the main prize will be a Miniature Research Cup.

On Wednesday the ladies will take a bus ride in Pittsburgh and will sample the 57 varieties of Heinz products.

THE A. S. H. V. E. RESEARCH LABORATORY AT U. S. BUREAU OF MINES, PITTSBURGH

Reduced Railroad Rates for Pittsburgh Meeting

1.—Round trip tickets will be sold from points in the United States and Canada, one and one-half fare on identification certificates.

2.—Identification certificates will be furnished to each member prior to January 1st.

3.—Tickets may be bought during the week preceding the meeting and final return limit is February 4 for middle western territory and in other territories, depending upon distance to Pittsburgh.

4.—Tickets from Pacific Coast points and other special territories at regular round trip winter tourist rates are often cheaper than reduced fare on the certificate plan. Inquiries should be made of ticket agent.

5.—Round trip tickets with thirty day return limit are sold at fare and three-fifths.

6.—When purchasing tickets members will surrender identification certificate to agent.

7.—Return portion of tickets must be validated at Pittsburgh before boarding train for return trip.

ROUND TRIP TICKETS WILL BE SOLD FROM

New England territory: Selling dates January 22 to 28, return limit February 4.

Eastern territory including Buffalo, N. Y., to Norfolk, Va.: Selling dates January 22 to 28, final return limit February 4.

Central territory, west of Pittsburgh, to Chicago and south to St. Louis: Selling dates January 22 to 28, final return limit February 4.

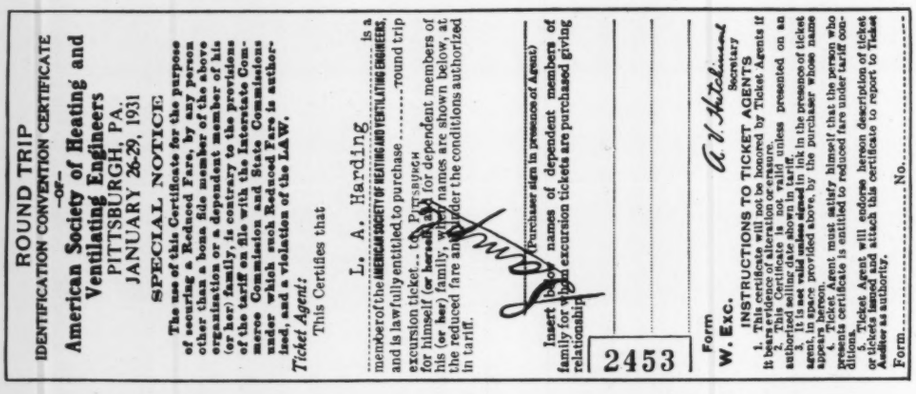
Southeastern territory, east of Mississippi River, south of Ohio and Potomac Rivers: Selling dates January 22 to 28, final return limit February 4.

Southwestern territory from St. Louis, south of Missouri and west of Mississippi Rivers: Selling dates January 21 to 28, final return limit February 4.

Western territory, all states west of Chicago except Pacific Coast states: Selling dates January 20 to 28, final return limit from February 4 to 11, depending on distance from Pittsburgh.

Pacific Coast, use winter tourist round trip tickets.

Canadian territory, tickets on sale January 20 to 28, final return limit February 4, except Alberta and British Columbia.



ROUND TRIP
IDENTIFICATION CONVENTION CERTIFICATE
—OF—
American Society of Heating and Ventilating Engineers
PITTSBURGH, PA.
JANUARY 26-29, 1931

SPECIAL NOTICE

The use of this Certificate for the purpose of securing a Reduced Fare, by any person other than a bona fide member of the above organization or a dependent member of his (or her) family, is contrary to the provisions of the tariff on file with the Interstate Commerce Commission and State Commissions under which such Reduced Fare is authorized, and a violation of the LAW.

Ticket Agent:

This Certifies that

L. A. Harding

.....is a member of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, and is lawfully entitled to purchase.....round trip excursion ticket... to PITTSBURGH for himself (or herself) and for dependent members of his (or her) family, whose names are shown below, at the reduced fare and under the conditions authorized in tariff.

(Purchaser sign in presence of Agent)

Insert below names of dependent members of family for whom excursion tickets are purchased giving relationship

2453

Form W. Exc.

A. V. Kitchener
Secretary

INSTRUCTIONS TO TICKET AGENTS

1. This certificate will not be honored by Ticket Agents if it bears erasures or alterations.

2. This Certificate is not valid unless presented on an authorized selling date shown in tariff.

3. It is not valid unless signed in ink in the presence of ticket agent, in the space provided above, by the purchaser whose name appears hereon.

4. Ticket Agent must satisfy himself that the person who presents certificate is entitled to reduced fare under tariff conditions.

5. Ticket Agent will endorse hereon description of ticket or tickets issued and attach this certificate to report to Ticket Auditor as authority.

Form.....No.....

The Annual Banquet will start at 7:30 p. m. in the Urban Room, William Penn Hotel, and after dinner the membership campaign awards will be made and the Past President's Emblem will be presented. A musical entertainment will be given by famous radio artists and dancing will follow.

On Thursday, the ladies will have a shopping trip to various Pittsburgh stores.

Pittsburgh is easy to reach by train and the railroads have granted *fare and one-half* on the *identification certificate* plan. Each member will receive a certificate by mail from the Secretary's office and this, when presented at the railroad ticket office, will entitle the member and members of his family to purchase a round trip ticket from his home city to Pittsburgh for *one and one-half* the regular round trip fare. Tickets may be bought during the week preceding the meeting and will be honored for the return trip until February 4th.

A 30-day return limit ticket may be purchased at slightly greater than fare and a half for the round trip. The member should specify his choice when making ticket purchase. These reduced fare tickets must be validated for the return trip by the agent in Pittsburgh before boarding train.

Special reservations are being made by various Chapters who will travel in a group and members are urged to communicate with local Chapter Secretaries and arrange to get aboard the Pittsburgh Specials.

Prior to January 1, members will receive hotel reservation cards and these should be promptly mailed to the William Penn Hotel.

MAKE EARLY ROOM RESERVATIONS

Special *business reply cards* will be mailed to each member of the Society prior to January 1 and hotel accommodations should be reserved promptly for the 37th Annual Meeting at the William Penn Hotel. Rates for rooms are:

Single Rooms with bath—$3.50, $4, $4.50, $5, $6 and $7 per day.
Double Rooms with bath—$6.50, $7, $7.50, $8.50 and $10 per day.
Rooms with twin beds and bath—$7, $8, $9 and $10.

Registration for the 37th Annual Meeting will open Monday morning, January 26. Badges and programs will be distributed as well as advance copies of papers to be presented.

The Officers and Committees of the Pittsburgh Chapter are making every effort to provide an attractive program and hope to entertain the Society's greatest Annual Meeting.

Committee on Arrangements

H. Lee Moore, General Chairman.
H. B. Orr, Chairman Reception Committee.
F. C. Houghten, Chairman Program Committee.
R. B. Stanger, Chairman Entertainment Committee.
F. A. Gunther, Chairman Banquet Committee.
W. W. Stevenson, Chairman Transportation Committee.
J. E. McGinness, Chairman Publicity Committee.
F. C. McIntosh, Chairman Finance Committee.

Method of Choosing Location of, Financing and Conducting Meetings of the Society

Resolved: That inasmuch as the Annual and Semi-Annual Meetings of the Society come under the jurisdiction of the Council, the following rules governing the handling of such meetings be adopted by the Council and published in the Journal of the Society at least twice during every year, preferably just prior to each meeting:

1—The Council will select the city in which the Annual or Semi-Annual Meeting is to be held, giving due consideration to the invitations received from Chapters or members as well as to the advisability of so distributing those meetings as to make them of the greatest advantage to the general membership, and to reduce as far as possible the expense of members attending.

2—That an appropriation be made to cover the entertainment or local expenses, incurred in connection with the meeting not exceeding $500.00, the regular meeting expense to be taken care of by the General Fund of the Society in the regular way.

3—That no registration fee or compulsory obligations of any nature be imposed on members or guests.

4—That the purchase of tickets for banquets or for any other form of entertainment that may be provided be entirely voluntary.

5—That the grouping of features and the same of tickets for group features be discouraged.

6—That the raising of Funds from manufacturers of heating apparatus be discouraged.

7—That the display of samples, or of literature, advertising the product of any manufacturer in any way, shape or form, be not permitted at the booths, registration desk, or in or about the meetings.

8—That the distribution of trade papers be entirely at the discretion of the committee in charge.

9—That the local Chapter, or local members, be empowered to form a General Committee with such sub-committees as may be required to handle the details of transportation, hotel accommodations, entertainment, finance, etc., and that this General Committee be requested to confer frequently with the Council, through the Secretary of the Society, and to make frequent reports on progress in connection with the various matters being handled by them.

10—That the arrangements of elaborate and costly entertainment features be discouraged.

Adopted at Council Meeting, January 29, 1926.

PROGRAM

37th Annual Meeting

American Society of Heating and Ventilating Engineers

William Penn Hotel **January 26-29, 1931** **Pittsburgh, Pa.**

SCHEDULE OF EVENTS

JANUARY 26

Monday —A.M.
9:00—Registration (William Penn Hotel).
10:00—Council Meeting.
P.M.
12:30—Luncheon for Council and Authors.
2:00—First Technical Session (William Penn Hotel).
9:00—A Night in Pirate Hall (William Penn Hotel).

JANUARY 27

Tuesday —A.M.
8:00—Breakfast Meeting—Committee on Research.
9:30—Second Technical Session (William Penn Hotel).
11:00—Breakfast Bridge for Ladies.
P.M.
2:00—Third Technical Session (William Penn Hotel).
6:30—Annual Dinner—Past Presidents.
Dinner for Wives of Past Presidents.
8:30—Miniature Championship Golf Tournament (William Penn Miniature Course).

JANUARY 28

Wednesday—A.M.
9:30—Fourth Technical Session (A.S.H.V.E. Laboratory, 4800 Forbes St.).
11:00—Sightseeing Trip for Ladies—Lunch at Heinz.
P.M.
2:30—Inspection of A.S.H.V.E. Laboratory—Bureau of Mines—Carnegie Institute of Technology.
7:30—Annual Banquet and Dance—Urban Room (William Penn Hotel).

JANUARY 29

Thursday —A.M.
9:30—Fifth Technical Session (William Penn Hotel).
11:00—Shopping Trip at Kaufmans—Luncheon for Ladies.
P.M.
2:00—Sixth Technical Session (William Penn Hotel).
4:30—Council Meeting (Organization of 1931 Council).

TECHNICAL PROGRAM

FIRST SESSION, MONDAY, JANUARY 26

2:00—Greeting.
Response—Pres. L. A. Harding.
Report of Council.
Report of Secretary.
Progress of Heating and Ventilating during the Past Quarter Century by R. P. Bolton.
Developments in Heating and Ventilation during 1930, by S. R. Lewis.
Heating Effect of Radiators, by R. V. Frost.
Committee on Code for Testing and Rating Concealed Gravity Type Radiation, by R. N. Trane, *Chairman*.
Report of Tellers.

SECOND SESSION, TUESDAY, JANUARY 27

A.M.
9:30—Report of Publication Committee—Prof. G. L. Larson.
Report of Guide Publication Committee—D. S. Boyden.
Development of the Ventilation System of the Holland Tunnel, by A. C. Davis.
Noise Reduction in Ventilation Units, by Warren Ewald.
Noise and Ventilation, by G. T. Stanton.
Some Studies on the Absorption of Noise in Ventilating Ducts, by G. L. Larson and R. F. Norris.
Report of Membership Committee—John D. Cassell.
Report of Increase of Membership—C. W. Farrar.

THIRD SESSION, TUESDAY, JANUARY 27

P.M.
2:00—Report of Finance Committee—F. C. McIntosh.
Air Conditioning as Applied to Furniture, Fixtures and Other Interior Woodwork, by D. R. Brewster.
Air Conditioning in the Bakery, by W. L. Fleisher.
Air Conditioning for Railway Cars, by A. H. Candee.
Committee on Oil Burning Devices by L. E. Seeley, *Chairman*.

FOURTH SESSION, WEDNESDAY, JANUARY 28

A.M.
9:30—Report of Research Committee—Prof. F. B. Rowley, *Chairman*.
Report of the Research Director—F. C. Houghten.
Air Leakage through Various Forms of Building Construction, by F. C. Houghten, Carl Gutberlet and C. A. Herbert.
Capacity of Return Mains for Steam and Vapor Heating Systems, by F. C. Houghten and Carl Gutberlet.
Welded Piping for Building Heating Systems, by F. G. Outcalt.
Air Pollution from the Engineers' Standpoint, by H. B. Meller.
Smoke and Dust Abatement, by M. D. Engle.

WEDNESDAY, JANUARY 28

P.M.
2:00—Inspection Trip—Research Laboratory.

FIFTH SESSION, THURSDAY, JANUARY 29

A.M.
9:30—Spectral Distribution of the Energy Radiated from Metallic Surfaces at High Temperatures, by G. R. Greenslade.
Insulating Effect of Successive Air Spaces Bounded by Bright Metallic Surfaces, by L. W. Schad.
Wind Velocities and Temperature Gradient Near Surfaces, by F. C. Houghten and Paul McDermott.

SIXTH SESSION, THURSDAY, JANUARY 29

P.M.
2:00—Utilization of Hot Springs for Heating in Iceland, by Ben Grondal.
Off-Peak System of Electric Heating, by Elliott Harrington.
Heating with Exhaust Steam, by Perry West.
Installation of Officers.
Announcement of Rules of Award for F. P. Anderson Medal.
Resolutions.
Adjournment.
4:30—Council Meeting (Organization of 1931 Council).

ENTERTAINMENT PROGRAM

JANUARY 26

Monday —P.M.
12:30—Luncheon for Council and Authors.
9:00—A Night in Pirate Hall (William Penn Hotel).
Westinghouse Program.
Music, Cards, Dancing, Buffet Supper.

JANUARY 27

Tuesday —A.M.
8:00—Breakfast Meeting—Committee on Research.
11:00—Breakfast Bridge for Ladies.
P.M.
6:30—Annual Dinner Past Presidents.
Dinner for Wives of Past Presidents.
8:30—Miniature Championship Golf Tournament for Miniature Research Cup (William Penn Miniature Course).

JANUARY 28

Wednesday—A.M.
11:00—Sightseeing trip for Ladies.
Lunch at Heinz.
P.M.
7:30—Annual Banquet and Dance—Urban Room (William Penn Hotel).

JANUARY 29

Thursday —A.M.
11:00—Shopping trip at Kaufmans.
Luncheon for Ladies.

NOMINATIONS FOR OFFICERS OF THE SOCIETY FOR 1931

The Nominating Committee appointed to select candidates for Officers of the Society for the coming year, 1931, takes pleasure in submitting the following list of nominees:

For President:
W. H. CARRIER, Newark, N. J.

For First Vice-President:
F. B. ROWLEY, Minneapolis, Minn.

For Second Vice-President:
W. T. JONES, Boston, Mass.

For Treasurer:
F. D. MENSING, Philadelphia, Pa.

For Members of the Council:

Three-Year Term

D. S. BOYDEN,* Boston, Mass.
E. K. CAMPBELL, Kansas City, Mo.
E. O. EASTWOOD, Seattle, Wash.
ROSWELL FARNHAM, Buffalo, N. Y.
E. HOLT GURNEY, Toronto, Ont.

Respectfully submitted,

NOMINATING COMMITTEE

G. L. LARSON, *Chairman*

Chapters	*Representative*
Cleveland	H. M. NOBIS
Illinois	J. F. HALE
Kansas City	N. W. DOWNES
Massachusetts	J. F. TUTTLE
Michigan	J. H. WALKER
Minnesota	G. C. MORGAN
New York	H. B. HEDGES
Western New York	O. K. DYER
Ontario	A. S. LEITCH
Pacific Northwest	E. O. EASTWOOD
Philadelphia	R. C. BOLSINGER
Pittsburgh	T. M. DUGAN
St. Louis	C. A. PICKETT
Wisconsin	G. L. LARSON

In accordance with the provisions of the Amended Constitution, as given, ballots containing the names of the above candidates will soon be sent to the membership for voting upon prior to the Annual Meeting in January.

Art. 9—Section 2. The Nominating Committee shall consist of a member designated by each Chapter, which shall effect its own organization and elect its own Chairman.

Section 3. The Committee may meet at the call of the Chairman, for discussion, but the official meeting shall be held at the Semi-Annual Meeting of the Society, at which time the candidates for each of the offices of the Society to be filled at the next Annual Meeting shall be selected by a majority vote of the members of the Committee present and voting. Five shall constitute a quorum.

Section 4. The Committee shall first secure the consent of all candidates selected, and shall, if possible, announce the names of the candidates at the Semi-Annual Meeting, but in any case the names of the candidates shall be certified to the Secretary of the Society at least four months before the next Annual Meeting. The Secretary shall publish these names in the October issue of THE JOURNAL.

Art. 10.—Section 3. The Secretary shall prepare ballots with the names of all candidates and forward them to the members at least thirty (30) days before the date of the Annual Meeting.

*Nominated to fill an unexpired term for two more years beginning 1931.

Nominations for Members of Committee on Research

Although committees of the Society are usually appointed, in view of the great importance of the Committee on Research and the financial responsibility it would be called upon to assume, it has been made more representative of the entire membership of the Society by a process of *election*. The election is governed by the By-Laws for the election of officers, with the single exception, that Members of the Committee on Research are nominated by the Council instead of by a Nominating Committee.

In accordance with the Regulations for the government of the Research Laboratory, adopted at the January, 1919, Meeting, and revised January, 1930, the Council announces the nomination of the following members of the Committee for election to succeed those members whose present terms expire January, 1931:

C. A. BOOTH, Buffalo, N. Y.
F. B. HOWELL, New York, N. Y.
WALTER KLIE, Cleveland, O.
F. B. ROWLEY, Minneapolis, Minn.
J. H. WALKER, Detroit, Mich.

The regulations governing the nomination and election of members of the Committee on Research are as follows:

SECTION I—ORGANIZATION

Research Committee

1. There shall be a standing committee known as the Research Committtee, consisting of fifteen members, each serving for three years, and five retiring each year.

a. The Council shall nominate previous to October first of each year five members to fill the vacancies of those retiring at the next Annual Meeting.

b. The nominations made by the Council shall be published in the October issue of the Society's Journal.

c. Prior to December first of any year, any ten members, over their own signatures, may nominate one or more additional members of the Research Committee, and such additional nominations shall be placed on the ballot opposite the nominations made by the Council.

d. The election shall otherwise conform to the regulations provided for the election of officers of the Society.

e. Vacancies may be filled by the Council, such persons chosen by the Council to serve until a successor is elected at the next Annual Meeting.

Local Chapter Reports

Illinois

December 8, 1930. The speaker of the evening was J. M. Robb, Director of Service of the Herman Nelson Corp. Mr. Robb stated that the practice of heating contractors giving an unlimited guaranty on the heating plant was confusing the channels of authority and obscuring the recognition of the purchaser's share of the responsibility for the results obtained. The speaker emphasized the thought that the proper heating diagnosis will hasten the time when the entire responsibility of the heating plant will not be placed on the contractor, and the designer and the purchaser will have an equal share in the responsibility for the results obtained.

H. G. Thomas read a report of the committee on the investigation of the feasibility of establishing a better relations commission. This committee report recommended that the chairman of the committee be given the power to draft a letter for the president's signature inviting the *Sheet Metal Contractors Association,* the *Master Steamfitters Association,* the *Illinois Society of Architects* and the *Consulting Engineers* to meet with the Society Committee for the purpose of discussing the organization of the commission; also a letter addressed to the president of the Society calling his attention to a movement in various cities to create a Building Congress or other similar association, and that in this letter the president be respectfully requested to bring before the Council for discussion the desirability of having a standing committee to guide the Society in the proper procedure for the best interests of the heating, ventilating and engineering groups in this major movement. It was pointed out that the several organizations mentioned were all ready to act upon official action by this Chapter.

Mr. Sutcliffe called attention to the annual meeting in January at Pittsburgh on January 26-29, 1931. He urged attendance by representatives from this District. He announced that the secretary would officially attend and would be expected to report at the next following meeting of the Chapter.

November 10, 1930. Seventy-one members and guests attended the dinner which preceded the meeting of the Illinois Chapter, held at the Hotel Sherman, Chicago.

Following the reading of the minutes of the previous meeting, Pres. A. G. Sutcliffe introduced D. D. Kimball, consulting engineer of New York City, and extended the greetings of the Illinois Chapter to the New York Chapter, through Mr. Kimball.

Dr. F. G. Honnold, Secretary of the Illinois Coal Bureau, was then introduced by President Sutcliffe. Dr. Honnold presented an interesting summary of the smoke abatement ordinance, and the part played by the coal bureau.

Joseph Harrington, combustion engineer, then gave a very complete and interesting talk on the use of stokers in connection with the smoke abatement and fuel economy campaign. A very interesting discussion followed Mr. Harrington's talk, and before the meeting adjourned a vote of thanks was given to the speakers for the courtesy extended to the Illinois Chapter.

Kansas City

November 10, 1930. Twenty members and guests of the Kansas City Chapter of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS had dinner at the Ambassador Hotel. Six members arrived after dinner, but fortunately in time to enjoy the evening program arranged by J. M. Arthur, Jr., Vice-President.

President Campbell called the meeting to order, dispensed with the regular roll call, and launched an appeal for a larger attendance from Kansas City Chapter at the Annual Meeting to be held in January at Pittsburgh, Pa.

Following the report given by Treasurer Lewis, Mr. Miard, a guest, outlined plans for the Power Show to be held in Kansas City in October, 1931, under the auspices of the *National Association of Power Engineers.*

It was moved by Mr. Hitchcock, and seconded by David Caleb, that W. H. Carrier, Vice-President of the Society, be urged to attend this Southwest Power Conference.

The guest speaker of the evening was C. L. Bailey, Republic Steel Corp., who showed a U. S. Bureau of Mines film, and gave an enlightening talk on alloy material versus carbon steel products. Mr. Bailey's vast experience and knowledge of his subject held the interest of everyone present until the meeting was adjourned.

October 15, 1930. At the October meeting the Kansas City Chapter was host to the members of the *American Society of Mechanical Engineers, American Society of Civil Engineers, American Institute of Electrical Engineers, American Chemical Society, American Institute of Architecture, Architectural League of Kansas City, Engineers Club and the National Association of Power Engineers.*

The Kansas City Chapter were highly honored by having as their guests, at this meeting, such prominent Society men as Pres. L. A. Harding, A. V. Hutchinson, Secretary, F. C. Houghten, Director of the Society's Research Laboratory at Pittsburgh, and C. W. Farrar, Chairman of the Committee on Increase of Membership of the Society.

President Campbell, who presided over this meeting, met President Harding's party at the train, and through the courtesy of Mr. Dodds, breakfast was served to them at the Kansas City Club.

At noon a luncheon meeting was held at the Kansas City Athletic Club for the Kansas City Chapter members only. At this gathering, consisting of 18 members, short talks were made by President Harding, Mr. Houghten and Mr. Farrar.

At the regular evening meeting there were 187 members and guests present, who enjoyed the address by President Harding on the Utilization of the Sun's Energy, which was a scholarly review of man's attempt to produce motive power with solar engines as the prime movers. His talk was full of humor and replete with scientific data and observations.

The next speaker of the evening was Mr. Houghten, whose address was in a measure supplementary to President Harding's. Mr. Houghten's talk was also illustrated, and showed clearly the high character of scientific research being carried on at the Society's Research Laboratory in Pittsburgh.

This meeting was the first of a series of joint meetings planned for the Kansas City engineering fraternities and was generally regarded as being highly successful.

Massachusetts

December 1, 1930. The final meeting of the year of the Massachusetts Chapter was held at the Chamber of Commerce Bldg., Boston, with an attendance of 38 members and guests.

After dinner Pres. R. F. McCoy introduced C. W. Farrar, Buffalo, N. Y., Treasurer of the Society and Chairman of the Committee on Increase of Membership, who spoke briefly on the necessity of getting new members and of the opportunities at hand for getting them.

President McCoy then called upon A. V. Hutchinson, Secre-

tary of the Society, who gave some interesting statistical data about the Society.

W. T. Jones was then asked to introduce the guest speaker of the evening, L. A. Harding, President of the Society. Mr. Jones performed his mission well, giving the members and guests an excellent idea of the capacity of the man who was about to address them.

President Harding delivered one of his interesting lectures on the Utilization of the Sun's Energy, illustrating his talk with lantern slides. He described various types of apparatus designed by eminent engineers and intended for using the sun's energy; none of these, he stated, was efficient compared to an equivalent possible energy of 5,000 hp per acre.

President Harding further illustrated engineering possibilities for power, both in warm Southern waters and in cold Northern waters, taking advantage of the temperature difference in the water at varying depths.

He also showed that in various parts of the world plants have been erected for utilizing the sun's energy with considerable success, so far as fulfilling the purpose is concerned, but involving perhaps unwarranted expense from an efficiency point of view.

Following the lecture numerous questions were asked and very ably answered by President Harding.

Before adjournment President McCoy expressed the sentiment of all who attended to the distinguished visitors.

November 10, 1930. The November meeting of the Massachusetts Chapter was held at the Kendall Square Bldg., Cambridge, and in the absence of President McCoy, W. T. Jones presided.

The Massachusetts Chapter members together with the members of the *Heating and Piping Contractors Association* of Boston were entertained by the Baker Supply Co. Over 100 enjoyed a turkey dinner furnished by the hosts, and C. P. Matthews, Warren-Webster Co., was presented with a handsome cigar lighter.

After a short address of welcome, Mr. Jones fittingly expressed the appreciation of all present, and a rising vote of thanks was extended to the hosts.

J. A. McCarthy, representing Baker Supply Co., gave an interesting address on the application of special fittings to welded pipe lines, which was followed by a talk on the progress in recent years in the manufacture and performance of steam traps, given by Henry Dusenberry, Wright-Austin Co.

The members and guests enjoyed the evening and were sorry that business detained Mr. Baker in Chicago so that he could not be with the engineers and guests who accepted his hospitality.

Minnesota

November 15, 1930. The Minnesota Chapter was host to 85, members, their wives and friends at the November gathering of the Chapter.

The occasion was a dinner-dance at the Interlachen Country Club, which took the place of the regular November meeting, and was the get-together party promised the Chapter members at the Semi-Annual Meeting in June.

A seven course dinner was served, followed by music and dancing which was thoroughly enjoyed until the early hours of the morning.

New York

December 15, 1930. The December meeting consisted of an inspection tour of the Westinghouse Lighting Institute.

After enjoying a dinner at the Home Making Center, a business meeting was held in the Little Theater of the Lighting Institute. The provisions relative to heating and ventilation of the proposed building code of the Merchants Association of New York, were brought up for discussion. The sections of the proposed code relating to heating and ventilation were read by Mr. Ralston, who was chairman of the sub-committee dealing with this portion of the code. Those entering into the discussion were Messrs. West, Goodwin, Carrier, Nichols and McKiever, and from the tenor of the remarks, the code is somewhat inadequate in certain respects. The report of the committee, however, was accepted with regrets that more time was not available for study and discussion.

After adjournment of the business session, the meeting was turned over to Ralph Newmuller, Director of the Westinghouse Lighting Institute and who explained the need it fulfilled. A demonstration of the developments in lighting during the past 25 years was given, and the original carbon filament electric light was contrasted with ultra-modern lighting devices.

L. J. Murphy of the Westinghouse organization submitted information on motors, particularly with respect to those used in connection with heating and ventilation systems. He discussed quietness of operation and also the possibilities of complete automatic heating, lighting and ventilating control in buildings in which no windows are installed.

After the showing of two comic pictures, the group was divided into parties and taken on a tour of inspection of the institute to inspect the various lighting exhibits. These included a classroom, a display room for selling textiles, and one for toys, and exhibits of transportation lighting, including railway, shipping and airport. Street lighting and traffic control systems also attracted the attention of those present. The industrial lighting department was of especial interest to a large number, particularly because of its utility as an accident-prevention measure. The tour of inspection of these exhibits was indeed interesting and enlightening.

November 17, 1930. Pres. L. A. Harding delivered the last of his series of Chapter talks on the Utilization of the Sun's Energy at this meeting. He was accompanied by Director F. C. Houghten of the A. S. H. V. E. Research Laboratory, who spoke on The Effect of Solar Radiation on Heating and Air Conditioning Problems, and National Treasurer Cecil Farrar, who spoke on membership.

Mr. Harding's lecture was extremely interesting to the 110 members and guests of the New York Chapter who attended this meeting and who listened attentively to his explanations of the historical outline of the investigations which have been made to utilize the power obtained from the sun and other natural sources. The most recent experiments of note, Mr. Harding explained, were those of Georges Claude who has succeeded in harnessing the gulf stream by making use of the power available due to the difference in temperature between the surface and sub-sea water. A pulse glass containing ether was displayed by Mr. Harding to illustrate the principle of obtaining power by means of a sufficient temperature difference.

Mr. Houghten's talk dealt with the experiments conducted at the Laboratory at Pittsburgh relative to the effect of heat capacity on the heat transmission through roofs in the summer time, and the consequent effect on the design of air conditioning systems. Mr. Houghten pointed out that the usual methods of estimating the heat loss through a roof during the summer time do not apply on account of the heat capacity of the structure, the percentage of error being proportional to the heat capacity.

Mr. Farrar aroused considerable enthusiasm over the membership campaign, and urged the members to endeavor to interest all possible candidates for membership in the Society. In his inimitable manner, he discussed ten points concerning membership in the Society and pointed out the advantages of such membership.

One of the features of the meeting was the presentation, to the past-presidents of the Chapter, of a token of esteem and appreciation for the services rendered by these gentlemen during their term of office. All but four of the living Chapter presidents were present.

Ontario

November 10, 1930. The Ontario Chapter of the A. S. H. V. E. held their first meeting of the season at Hunt's Tea Room, Toronto, with 26 members and guests present.

After the minutes of the previous meeting had been read and approved, F. C. Houghten, Director of the Society's Research Laboratory at Pittsburgh, delivered an address on Recent Investigations at the Research Laboratory and Their Applications.

Mr. Houghten dealt largely with pipe sizes, heat losses, and solar heat transfer through various building materials, which was very interesting to the members and guests present.

Pacific Northwest

November 13, 1930. The November meeting of the Pacific Northwest Chapter of the A. S. H. V. E. was held in the Gold Room of the New Washington Hotel, Seattle, and was a joint meeting with the members of the *American Society of Mechanical Engineers.*

The meeting was preceded by the usual dinner, and was presided over by Pres. E. O. Eastwood.

The State of Washington Game Preservation Department represented by J. Rowley and Miss L. Jones, showed an interesting film of the natural life of the state.

A. V. Hutchinson, Secretary of the Society, was the guest of honor, and was called upon for a short talk. Mr. Hutchinson explained the duties of the various Officers and Committees of the Society and what was being accomplished by each.

The minutes of the previous meeting were read and approved, followed by the treasurer's yearly report which was accepted as read.

Philadelphia

November 13, 1930. The regular November meeting of the Philadelphia Chapter was held at the Engineers Club, beginning with the special dinner in honor of Pres. L. A. Harding.

Other distinguished guests included F. C. Houghten, Director of the Society's Research Laboratory in Pittsburgh, C. W. Farrar, Chairman of the Committee on Increase of Membership, A. V. Hutchinson, Secretary of the Society, and J. G. Shodron, president of Wisconsin Chapter.

Following the dinner, the meeting was called to order by President Black, and a short business session was conducted.

M. F. Blankin, as Chairman of the Meetings Committee, called upon Mr. Touton of the Bayuk Cigar Co., who extended an invitation to the Philadelphia Chapter to attend the dinner and inspection of their plant at the regular meeting to be held in December.

A. C. Edgar, Chairman of the Nominating Committee, presented the following names as candidates for Chapter Officers and Board of Governors for 1931: *President,* E. N. Sanbern; *Vice-President,* L. C. Davidson; *Secretary,* W. P. Culbert; *Treasurer,* M. F. Blankin; *Board of Governors,* H. G. Black, J. H. Hucker and A. J. Nesbitt.

The meeting was then turned over to J. D. Cassell as Toastmaster of the evening. Mr. Cassell called upon Stewart A. Jellett, the first President of the Society, and at present an Honorary and Life Member, who reviewed the origin and early history of the Society.

H. P. Gant, President of the Society in 1923, spoke briefly on more recent history of the Society, particularly since 1923.

Thornton Lewis, President of the Society in 1929, was then asked to address the meeting. Mr. Lewis gave an interesting and impressive talk upon the work of the Society and its past accomplishments. He gave a number of reasons for the existence of such an organization as the Society, and outlined in detail the reasons why all engineers doing heating and ventilating work should belong to the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.

C. W. Farrar, Chairman of the Committee on Increase of Membership, then discussed the ways and means of increasing the present membership, outlining the type of engineers who should be invited to join.

A technical discussion followed Mr. Farrar's talk, which was given by the Director of the Research Laboratory, F. C. Houghten, who presented an illustrated talk on Heat Absorption from Solar Radiation.

Mr. Cassell next called upon A. V. Hutchinson, Secretary of the Society, who gave some interesting statistics in regard to financial conditions of the Society, and outlined briefly just how all money taken in is distributed among the various activities of the Society.

The chief speaker of the evening was then introduced by Mr. Cassell. President Harding gave a very interesting talk on the Utilization of the Sun's Energy. This was exceptionally well prepared and presented by President Harding, who is undoubtedly one of the most popular and most entertaining speakers among the Society membership. At the conclusion of President Harding's talk, a rising vote of thanks was extended him by the entire Philadelphia Chapter. It was the unanimous opinion of all those attending this meeting that President Harding's talk was one of the most interesting and instructive the Chapter has had for several years.

Pittsburgh

November 3, 1930. The regular monthly meeting of the Pittsburgh Chapter of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS was held in the Assembly Room of the Fort Pitt Hotel, Pittsburgh. After an informal dinner, President Stevenson called the meeting to order with 40 members and guests in attendance.

The Nominating Committee submitted its report of officers for 1931. Election to be announced in December.

S. E. Dibble moved, that in accordance with the wishes of Mr. Eicher of the Department of Education of the Commonwealth of Pennsylvania, the President be authorized to appoint a committee of three members to consult with a committee of members from the Philadelphia Chapter on matters connected with the heating and ventilation of schools. The motion was seconded by F. C. McIntosh and unanimously carried.

In accordance with the motion by Professor Dibble, President Stevenson appointed the following committee: G. C. McEllroy, H. Lee Moore and R. J. J. Tennant.

The Secretary, J. L. Blackshaw, then read a letter from C. W. Farrar, urging the Pittsburgh Chapter to increase its membership, and suggesting methods of so doing.

H. Lee Moore, General Chairman for the Annual Meeting in January, stated that the 37th Annual Meeting of the Society would be held at the Hotel William Penn, during the last week of January, and announced that the Chairman of each Committee was at liberty to call on the entire membership for support and help. Mr. Moore also outlined some of the tentative plans for the meeting.

A. V. Hutchinson, in his address, stated that because this was the first annual meeting which Pittsburgh had ever entertained, there would be much interest taken in it, especially in the Laboratory of the Society. Mr. Hutchinson also mentioned that he knew of four men who planned to come from the Pacific Coast.

Mr. Houghten announced that Prof. F. B. Rowley of the Experimental Engineering Laboratories of the University of Minnesota, and Second Vice-President of the Society, was to address the December meeting of the Pittsburgh Chapter.

Pres. L. A. Harding, Buffalo, N. Y., then addressed the meeting, calling attention to the present condition of the Society —that it does a business of $110,000 a year, 40 per cent of which goes to the operation of the Research Laboratory and the cooperation of this Society with research in ten Universities.

He presented an illustrated talk on the Utilization of the Sun's Energy, stating in brief; that the standard method of measuring the sun's intensity was with the aid of a Smithsonian Institute water-flow silver disc pyroheliometer, the operation of which he explained. President Harding gave some of Director Houghten's results, and explained the workings of sun radiant energy absorbers and engines of various experimenters.

A rising vote of thanks was extended to President Harding and the other officers, which was followed by adjournment.

St. Louis

November 5, 1930. The St. Louis Chapter of the Society held its regular dinner meeting at the Roosevelt Hotel, with 21 members and guests attending, and Pres. E. A. White the presiding officer.

Following the reading of the minutes of the previous meeting, which were read and approved, C. R. Davis read a letter from H. D. Balsinger, Chairman of the Nominating Committee, advising that the Committee had met and had selected the following members to be nominated for the officers of the Chapter for 1931: *President,* R. M. Rosebrough; *First Vice-President,* J. M. Foster; *Second Vice-President,* C. A. Pickett; *Secretary,* C. R. Davis; *Treasurer,* A. L. Walters; *Board of Governors,* E. A. White, Geo. Myers, J. F. McMorran and L. Walter Moon.

President White then read a letter from E. K. Campbell, President of the Kansas City Chapter of the Society, who advised that a meeting of the various engineering organizations in Kansas City had been held for the purpose of endeavoring to secure in the next legislature of the Chapter, a law requiring licensing of architects. In the discussion it was brought out that so far the St. Louis Chapter had received no such request, and President White proposed answering the letter accordingly.

The St. Louis Chapter was honored at this meeting by the presence of Paul Sodemann, the former Secretary. Mr. Sodemann when called upon expressed a fondness for Chicago, although he was glad to meet with the members of the St. Louis Chapter once again. He also gave some information relative to the heating and ventilating course at the Rankin Trade School.

The first speaker of the evening, C. G. Buder, gave a very explicit discourse on automatic firing, going into detail in explaining the various types of stokers.

C. R. Davis presented a paper on pneumatic temperature control, and following Mr. Davis' talk, E. B. Evleth spoke on electrical temperature regulation. Both Mr. Davis and Mr. Evleth handled their subjects well and answered numerous questions brought about in discussion.

E. E. Carlson gave a brief history of temperature control and enumerated many usages to which it can be applied.

A rising vote of thanks was then extended to the speakers in appreciation of their efforts.

Cleveland

October 6, 1930. The first meeting of the Cleveland Chapter was held in the rooms of the Cleveland Engineering Society, Cleveland, Ohio.

This was a joint meeting with the *American Society of Mechanical Engineers,* and Prof. A. P. Kratz, University of Illinois, gave an illustrated talk on Research in House Heating. He particularly discussed tests made and results obtained in the Warm Air Heating Research Residence in the University of Illinois, illustrating his talk with slides.

The efficiencies obtained with various fuels and results obtained under varying conditions were fully discussed, much to the interest of the engineers present who joined in the discussion following Professor Kratz's talk.

Membership Increasing Rapidly

As the campaign to extend the Society's membership draws to a close (Jan. 15, 1931) it is evident that unusually good results were obtained by the individual members in picking their candidates. The rewards will be presented at the 37th Annual Banquet at the William Penn Hotel, January 28, 1931.

Now for the last lap in the race—here are

"TEN SPOTS"

where new members may be found:

First—Student members are to be found in Universities and Colleges.

Second—Engineers will find candidates among their friends in the profession.

Third—Members may be secured from architects' offices where the specification writers are interested in heating and ventilating.

Fourth—Salesmen of heating and ventilating apparatus are prospective members.

Fifth—Industrial engineers in factories should be interested as they usually control heating, ventilating and air conditioning installations.

Sixth—City employes—especially those interested in school heating and ventilating work—should be invited.

Seventh—Engineers in charge of mechanical equipment of schools and large office buildings should be interested.

Eighth—Department heads in jobbing houses who have charge of engineering and the sale of heating and ventilating apparatus.

Ninth—Engineers doing contracting work, heating and ventilating.

Tenth—Professors in colleges and universities interested in research or in giving instruction on heating and ventilating.

Professor Kratz also discussed heating systems in general, particularly applying to questions that were asked relating to the research work done at the University of Illinois.

December Council Meeting in New York

The majority of the Council attended the December 2 meeting at the Headquarters Office of the Society, 51 Madison Ave., New York, and when Pres. L. A. Harding called the meeting to order the following men responded: H. H. Angus, D. S. Boyden, R. H. Carpenter, W. H. Carrier, J. D. Cassell, Roswell Farnham, C. W. Farrar, W. T. Jones, G. L. Larson, F. C. McIntosh, F. B. Rowley and A. V. Hutchinson, Secretary.

Among the important matters acted upon were—Approval of the Annual Meeting Program; Re-Appointment of D. S. Boyden as Chairman of the Guide Publication Committee; Approval of the Safety Code for Mechanical Refrigeration, submitted by the *American Standards Association* and consideration of the Report of Committee on Chapter Relations as well as special and routine items.

December Election

In the list of Candidates Elected as published in the December Journal the address of Daniel A. MacKinnon should have appeared as follows:

Daniel A. MacKinnon, Sales Engr., English & Lauer, Inc., 1224 S. San Pedro St., Los Angeles, Calif.

Eightieth Anniversary

By J. J. Wilson

Charter Member and Life Member American Society of Heating and Ventilating Engineers.

I'm sending you the latest news,
And then a little more:
To say I'm just a jolly kid.
Today my age four-score.

Few are the friends that now remain
From the golden days of yore
When my age was only twenty
And now it's four times more.

Yes, thanks, I'm very well;
In fact, I'm feeling fine.
It keeps me on the jump
To fight old Father Time.

My eyesight now has fled,
Of this I'll not complain;
But thank God for the blessings sent
To help me fight Life's game.

Now that this junk is off my chest,
Alas, the task is done;
I'll say Adieu, but not goodby,
Until I'm eighty-one.

Death of Allen Hubbard

Allen Hubbard, a prominent member of the Society, and a member of the Boston consulting engineering firm of Hollis French and Allen Hubbard, died at Newton Hospital, Boston, December 14th, 1930.

Mr. Hubbard was born in Westfield, Mass., December 9, 1860, where he attended school until he entered Yale with the Class of 1883. From New Haven he returned to Westfield to begin practical training for his life work. He made the first plans for heating systems that The H. B. Smith Co. ever had, later working for several years in Providence for the same company.

He then came to Boston, where for a few years he worked with A. B. Franklin, one of the pioneer heating contractors. It was at this time that he came to know so many of the men who in years following have risen to such prominence in the heating and ventilating business in New England. One of the greatest sources of satisfaction to him has been the continued contacts with these friends of younger days.

In 1899 he entered into partnership with Hollis French. The success and achievements of this firm are too well known to need recounting.

In his community, Mr. Hubbard was as active as he was in his profession. He played an important part in the organization and maintenance of several clubs and always bore his share of charitable and philanthropic work. He was affiliated with the following organizations: Charles River Country Club, Brae Burn Club, University Club, Exchange Club, Engineers Club, Yale Club, Boston Chamber of Commerce, Tananpo Club, Hollywood Club, *American Society of Mechanical Engineers,* Chi Phi Fraternity, the *American Institute of Consulting Engineers,* as well as the American Society of Heating and Ventilating Engineers.

The Engineering Fraternity, his associates, friends and family have lost one who filled a position far greater than a successful engineer, for his spirit of Christian kindness and nobility of soul have always been a source of inspiration to all those about him. The officers and Council of the Society deeply regret the passing of Mr. Hubbard.

Guide Available January 15, 1931

The Guide 1931 will be off the press about January 15, 1931.

The subject of heat losses from buildings, formerly covered in one chapter, is treated in this issue of The Guide in four separate chapters in a logical and concise manner. New data are included on infiltration losses, fan-furnace and fan-steam heating systems, radiators and convectors, boilers and heaters, chimneys, solid and liquid fuels, electric heating, exhaust steam heating, district heating, automatic temperature and humidity control, pipe and pipe insulation, and pumps and traps. The subjects of ventilation standards and systems, air conditioning, ducts, registers and grilles, and fans and motive power have been greatly amplified and improved.

The Technical Data section of The Guide 1931 has been compiled by carefully selected engineers, each a specialist in the subject on which he has prepared data. Since The Guide is revised annually by men of outstanding ability, this reference book has become the accepted authority in the heating and ventilating field, and has been found indispensable to designers, engineers, architects, contractors and manufacturers who require up-to-the-minute information on all phases of their profession and industry.

CANDIDATES FOR MEMBERSHIP

The Constitution of the Society, as now amended, requires the following mode of procedure in voting on applicants for membership in the Society. All applications for membership are to be sent to the Secretary and the name of applicants and their references shall be printed in the next issue of the Journal of the Society or sent to the members in other approved manner as ordered by the Council. When replies are received from references, the Candidate's application shall be submitted to and acted upon by the Membership Committee as soon as possible.

When the Membership Committee has acted favorably upon a Candidate's application and assigned his grade, the Council shall vote upon the election of the proposed Candidate for membership by letter ballot. During the past month 32 applications for membership have been received and the names of these men and their sponsors are published in the following list.

Members are requested to scrutinize the list with care. The Membership Committee, and in turn the Council, urge the members to assume their share of the responsibility of receiving these candidates into membership by advising the Secretary promptly of any whose eligibility for membership is in any way questioned.

All correspondence in regard to such matters is strictly confidential, and is solely for the good of the Society, which it is the duty of every member to promote.

Unless objection is made by some members by January 15, 1931, these candidates will be balloted upon by the Council. Those elected to membership will be notified by the Secretary immediately after election.

CANDIDATES	REFERENCES	
	Proposers	*Seconders*
BARNETT, STEPHEN J., Sr. Partner, Barnett Brothers, Buffalo, N. Y.	Joseph Davis L. N. Castin	A. K. Tinker F. H. Burke
BODINGER, JACOB HARRIS, Pres., J. H. Bodinger Co., Inc., New York, N. Y.	F. W. Hanburger E. S. White	A. S. Armagnac Clifford Strock
BREDESEN, BERNHARD PALMER, Sales Repr., Herman Nelson Corp., Minneapolis, Minn.	Albert Buenger A. J. Huch	E. J. Uhl H. J. Sperzel
BRILL, JOSEPH W., Estimator, M. G. Lippincott, Hornell, New York.	Joseph Davis C. H. Love	H. S. Schall Wm. Roebuck, Jr.
BROWN, WILLIAM ARTHUR, Consulting Engineer, 205 East 42nd St., New York, N. Y.	V. J. Cucci E. J. Ritchie	Edward Blackburn R. W. Cumming
BRUST, OTTO, Chief Constr. Engr., Carrier Lufttechnische Gesellschaft, Stuttgart, Germany.	Herman Worsham L. L. Lewis	W. G. Hillen E. T. Murphy
BUR, JULIEN RAOUL C., Engineer, Bur et Cie, Dijon, France	W. H. McKiever A. S. Armagnac	A. V. Hutchinson A. D. Kelley, Jr.
ETHERIDGE, GEORGE THOMAS, JR., Student, Carnegie Institute of Technology, Pittsburgh, Pa.	S. E. Dibble G. M. Comstock	H. Lee Moore E. S. Tower
FARNSWORTH, JOHN GOSMAN, Central Illinois Light Co., Peoria, Ill.	F. L. Meyer R. S. Wallace (ASME)	E. D. Edwards (ASME) C. R. Bush (AIEE)
GILLESPIE, J. D., Pres., Gillespie & Tinkham, Los Angeles, Calif.	Leo Hungerford H. B. Keeling	C. S. Anderson Lee Updegraff
GORBANDT, EVERETT T., Buffalo Forge Co., Buffalo, N. Y.	H. L. Moore H. B. Orr	F. C. Houghten R. B. Stanger
HOYT, CHARLES WAKLEY, Treas., Wolverine Heating & Ventilating Co., Inc., Boston, Mass.	J. W. H. Myrick W. N. McKenna	F. I. Cooper W. T. Jones
HUMPHREYS, JAMES, McQuay Radiator Corp., New York, N. Y.	E. A. Kingsley R. H. Carpenter	H. W. Hochuli
JOHNS, CHARLES FREDERICK, Heating & Designing Engr., Enterprise Foundry Co., Ltd., Sackville, New Brunswick, Canada.	Prof. H. W. McKiel (EIC) Prof. F. L. West (EIC)	W. M. Tweedie Prof. Faulkner (EIC)
KEIST, WALTER EARL, W. J. Keist & Son, West View, Pittsburgh, Pa.	Roy Brauer M. R. Robinson	F. C. McIntosh S. E. Dibble
LANOU, J. ERNEST, Part Owner, F. S. Lanou & Son, Burlington, Vt.	F. L. Austin J. F. Tuttle	W. P. Mower C. R. Matthews
LUNDQUIST, RALPH A., Estimator, R. H. Baker Co., Cambridge, Mass.	R. H. Baker W. T. Jones	J. W. Brinton David Moulton

MAHONEY, DAVID JOHN, Branch Mgr., Johnson Service Co., Buffalo, N. Y. (*Advancement*)	L. A. Harding F. H. Burke	M. C. Beman N. W. Downes
MARKUSH, EMERY U., Mech. Engr., Weitbeer Plumbing Corp., New York, N. Y.	G. E. Olsen Raymond Newcomb	W. W. Timmis L. K. Berman
MARUM, OTTO, Plant Engr., Agfa Ansco Corp., Binghamton, N. Y.	Max Riewerts (ASME) Harry Holford (ASME)	Ludwig Holly (ASME) Robert Brown (ASME)
MCINDOE, JAMES FRANCIS, Branch Engr., American Radiator Co., Seattle, Wash.	W. W. Cox W. L. Dudley	William Mallis P. M. O'Connell
NESBITT, JOHN J., JR., John J. Nesbitt, Inc., Philadelphia, Pa.	A. C. Edgar M. F. Blankin	E. N. Sanbern A. J. Nesbitt
NORDHEIMER, CLYDE L., Student, Carnegie Institute of Technology, Pittsburgh, Pa.	S. E. Dibble G. M. Comstock	H. L. Moore E. S. Tower
ORR, GEORGE MILTON, Pres., G. M. Orr & Co., Minneapolis, Minn.	Albert Buenger A. J. Huch	L. C. Hanson H. J. Sperzel
OSMUNDSEN, HARRY B., Vice-Pres. & Sales Mgr., McQuay Radiator Co., New York, N. Y.	E. A. Kingsley R. H. Carpenter	H. W. Hochuli
OTT, RUSH CALVIN, Chief Engr., Peerless Unit Ventilation Co., Inc., Bridgeport, Conn.	H. P. Dempsey A. A. Criqui	R. D. Madison E. E. Johnson
POGALIES, LOUIS H., Wilbur Watson & Associates, Cleveland, Ohio.	H. M. Nobis F. H. Morris	W. C. Kammerer R. G. Davis
REESE, PHILIP R., Manager, Minneapolis Branch, Herman Nelson Corp., Minneapolis, Minn.	Albert Buenger A. J. Huch	E. J. Uhl H. J. Sperzel
ROSKE, FREDRICK MELVIN, Asst. Mgr., The H. Smith Co., Fair Haven, N. J.	H. P. Smith H. R. Birch	H. L. Hosking H. N. Booth
SALISBURY, WILLIAM CONYNE, Sales Engr., American Radiator Co., Detroit, Mich.	G. R. Atherton E. H. Clark	J. L. Fuller G. H. Giguere
SEEPE, RICHARD A., Sales Repr., Herman Nelson Corp., Minneapolis, Minn.	Albert Buenger A. J. Huch	E. J. Uhl H. J. Sperzel
ZINK, DAVID D., Branch Sales Engr., American Radiator Co., Kansas City, Mo.	F. F. Dodds N. W. Downes	Carl Clegg E. K. Campbell

Candidates Elected

In past issues of the Journal of the Society the names of the following men were listed as Candidates for Membership. The membership grade of each Candidate has been assigned by the Membership Committee and balloted upon by the Council. We are now instructed by the Council to post herewith, as required by Art. II, Sec. VIII, of the By-Laws, the following list of candidates elected:

MEMBERS

BERNSTROM, BERT, Lakeside Company, Hermansville, Mich.

CANDEE, ANDREW HALEY, General Engr., Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

EATON, VINCENT, Consulting Engr., 5007 Euclid Ave., Cleveland, Ohio.

GILLIAM, OLIVER FULGHAM, Sales Engr., York Heating & Ventilating Corp., Chicago, Ill. (*Advancement*)

HASHAGEN, JOHN B., Sales Engineer, Johnson Service Co., New York, N. Y.

JOHNSON, CARL E., Sterling Electric Motors, Inc., Los Angeles, Calif.

KEELING, HARRY B., Sales Engr., American Blower Corp., Los Angeles, Calif. (*Advancement*)

KNOX, JAMES ROSS, Asst. Heating Engr., Lord & Burnham Co., Irvington, N. Y.

LEWIS, J. CLIFFORD, President, Circulair Heat Co., Inc., Louisville, Ky. (*Reinstatement*)

SLATER, JEAN BERT, Howard Iron Works, Buffalo, N. Y.

TYSON, PERRY W., W. M. Anderson, Plumbers & Steamfitters, 600 Schuylkill Ave., Philadelphia, Pa.

VOISINET, WALTER E., Manager, Buffalo Office, The Herman Nelson Corp., Buffalo, N. Y.

WALLACE, BRUCE, Heating & Ventilating Engr., Own Business, Newmarket, Auckland, New Zealand.

ASSOCIATES

BUNKER, KENNETH S., Union Tank & Pipe Co., Los Angeles, Calif.

DELANCEY, RALPH W., Sales Mgr. & Designing Engr., Real-Oil-Heat Burner Co., Winona, Minn.

HERMAN, J. JR., Estimator, J. Herman Co., Los Angeles, Calif.

JUNIORS

BARNUM, WILLIS E., JR., Sales Engr., York Ice Machinery Corp., Los Angeles, Calif.

KENNEDY, MARON, Sales Engr., York Ice Machinery Corp., Los Angeles, Calif.

STUDENTS

SCHOENOFF, ALFRED EMIL, Student, Carnegie Institute of Technology, Pittsburgh, Pa.

Heating · Piping and Air Conditioning EDITORIALS

Replacing Manual Control

In almost all industries, the replacement of manual labor by an automatic machine will show reductions in operating costs and improvements in the product which soon pay for the first cost of the machine. This has been a cardinal principle of business since the industrial revolution.

In the same manner, automatic and semi-automatic control is usually more efficient than manual control. Especially is this true of air conditioning systems, where manual control is likely to be incidental to other duties and inaccurate because of the difficulty the man responsible for such control often has in recognizing small variations which may decidedly affect important manufacturing processes.

Different degrees of variation in the atmospheric conditions maintained are, of course, allowable in air conditioning systems. However, no matter for what process air is being conditioned, including air conditioning for health and comfort, it is well worth the time of any engineer to study the possibility of replacing manual control with automatic.

Cost of Operation and Maintenance

The cost of maintenance should be carefully analyzed at the inception of any project. It too often happens that the matter of first cost is allowed to overshadow the cost of upkeep—as an illustration of this, consider the installation of a piping job purely on a "first cost" basis. To renew the installation with the lower first cost may cost considerably more than the original contract when a better piping job in the first instance would have outlasted the useful life of the property.

There are instances without number where cheap power plant equipment has proved a disastrous experience. In some cases, this has been due to the fact that the purchase and installation of the apparatus has not been done under competent authority; in other words, where the man has not been "heavy" enough for the job. Frequently, the fault is that of the management's policies.

Always in considering maintenance cost comes the difficulty of drawing a fine line between the cost of operation and the cost of maintenance. Take as an illustration, two automobiles exactly similar. Place one in the hands of a careful operator, who will see to it that lubricating oil is properly changed at regular intervals, that all the bearings are properly greased and that the solution is kept in the battery at the proper level.

The other car falls into the hands of a careless owner and has no proper care of any kind.

The first car at the end of operating 20,000 miles will be, to all intents and purposes, in as good condition as when it came from the factory. The other one will be in need of extensive repairs, the cost of which the owner would probably charge up as maintenance where, as a matter of fact, it is not really a maintenance charge at all, but rather one of inefficient operation.

This illustration holds good all the way down the line from a building to the power plant in the factory, from the fan motor to the elevator.

Economic Inefficiency

Economic inefficiency—ponderous words, which are used sometimes by efficiency engineers to convey the idea that a thing does not pay. As to whether an investment pays or not, there are different points of view and different ways of arriving at a conclusion.

Equipment is to be added to a plant—how can the engineer determine whether or not it will pay? There is, of course, the first cost, and, many times, that is the only cost considered. On a certain type of equipment there should be a reasonable interval between the time of its purchase and the time when it is discarded. That is, it should last long enough; but, on the other hand, it should not last too long. A salesman usually makes a mistake these days in emphasizing that a device will last a great many years. It is seldom that anyone wants equipment to last too long, and he does not want to pay the additional cost which will enable the manufacturer to put into it these lasting qualities.

Where, then, is the balance between economy and obsolescence? How long should an air washer last and what should it cost under certain conditions in order to make it a profitable investment?

As a matter of fact, it would be helpful if manufacturers would provide with their other informa-

tion, data as to the economic obsolescence. How long should a boiler be made to last? How long should a unit heater be made to last? If the mechanical equipment of a plant is worth $100,000 and this equipment for a period of years (covering original cost, repairs and maintenance) renders an annual return on the investment of 6%, then may the equipment be said to have functioned with sufficient efficiency?

In industry, efficiency is ultimately measured in dollars and cents. Any data that can be furnished by the manufacturers of equipment on economic efficiency are of aid to the engineer responsible for the purchase of such equipment.

Check Cooling Equipment

In the summer months, the engineer in charge of a heating system takes the opportunity of putting his equipment in proper condition for the coming heating season. At that time the parts of the system that have given trouble during the winter are repaired and the entire set-up is checked thoroughly and overhauled.

Now is the time when many operating engineers have a chance to do the same thing with air cooling systems. During the peak load times of next summer, there will be no opportunity to take equipment out of operation for needed attention. The opportunity to do so should be taken now.

Failure of an air cooling system to function properly means, in practically all cases, a definite money-loss to the owner. Chances for such failure may be reduced to a minimum if the equipment goes into the summer months in top-notch shape.

That Thing Called Research

Several editorials have appeared in this paper on the subject of research. Some of them cite instances where research was used to find new markets and new uses. Some of them told of using research to resuscitate a waning market.

But there is something more fundamental about research. The inexorable law of the universe is change. Nothing can remain still and continue to live.

So, without dwelling upon the more apparent evidence of the value of research, or the more immediate returns from it, one may consider it as an underlying principle of all progress. Research results in change. In conducting research change is directed along certain lines. Change is sure to come in one way or another. What is more logical than to direct that change so that it will render greater benefits? Self-satisfaction is a brake of progress which sooner or later will bring it to a standstill.

Keep Posted

The annual meeting of the *American Society of Heating and Ventilating Engineers,* to be held the latter part of this month in Pittsburgh, promises something of value to almost all engineers and should certainly be of aid to air conditioning and heating engineers.

The heating system that is functioning satisfactorily and at a reasonable cost today may be an actual loss if modern equipment surpasses it in efficiency and in the more effective application of the fundamental principles. The heating engineer must keep posted.

With air conditioning daily growing of more and more importance to every industry, to the hotels, the office buildings, the hospitals, the schools, theaters, the railroads, not many engineers or architects can afford to miss the opportunity of learning all they can about its numerous phases. Air conditioning contractors, too, must keep up to the minute.

The program for the meeting looks particularly attractive—undoubtedly, Pittsburgh should be the headquarters of the majority of the engineers in the industry the end of this month.

Death for Air Pollution

The *New Yorker,* clever reviewer and critic of city life, recently published some comments on the amount of dust and smoke in New York City. In the same paragraphs appeared a reference to the first air pollution legislation, made some decades ago in London.

The penalty for the third violation of the London anti-smoke laws was death; according to the *New Yorker,* one man was actually hanged.

The death penalty is, to say the least, a little extreme for a condition brought on to a large extent by our mode of life; however, it behooves the engineering profession to pay increased attention to the problem of reducing pollution of the air over our cities. The public is showing increasing interest in the question as evidenced by recent legislation.

While the effects of unnecessary smoke, dust and dirt in the atmosphere may be in the realm of the doctors, the cause (and, therefore, the remedy) is a problem for the engineer in the heating and power fields.

The engineer is not shirking his responsibility; much has already been done to prevent air pollution through proper design, operation and the use of modern equipment. Research relating to the reduction of smoke, dust and dirt is continually being carried forward.

While the outdoor air of our large cities will probably never be as pure as that supplied to our buildings by modern air conditioning systems, everything points to further progress in the reduction of atmospheric pollution.

"Open for Discussion"

A department in which we follow the custom of technical societies in allotting space in their programs for discussion of the papers presented

Standardization of Nomenclature

"Suggested Reforms in Heating and Air Conditioning Nomenclature," *by Samuel R. Lewis.* Page 744, September, 1930, issue

MR. LEWIS' article in the September HEATING, PIPING AND AIR CONDITIONING should serve as the starting point for a definite and needed development in the field of heating nomenclature. A reasonable standardization of word usage in an industry is of particular value, not only to the consulting engineers and specification writers like Mr. Lewis, but particularly to the advertising and catalog writers and also to everyone else in the industry, as all are concerned with "thought transfer" as well as "heat transfer." The value of carefully defined and standardized nomenclature is well illustrated in the aeronautical industry, where this subject has been under the guidance of the National Advisory Committee for Aeronautics ever since the early days of the industry; the heating industry has had the benefit of no such guidance. It is certainly to be hoped that the proposed committee of the *A. S. H. V. E.* will develop into a controlling body functioning in this respect.

While the writer agrees with the fundamental objective expressed in Mr. Lewis' article to the effect that we should standardize our nomenclature, he disagrees with many of Mr. Lewis' individual ideas. Particularly, he does not feel that the problem involves the invention of new words, chiefly because there are insurmountable obstacles in the way of securing adoption of newly invented words. The needed improvements must come through elimination of inconsistencies and *standardization of use* of existing words in their proper fields.

Steam Pressures

Take the matter of steam pressure as an example. In the heating field, "low pressure" refers generally to pressures below five or ten lb. per sq. in. and "high pressure" may refer to anything from ten to one hundred lb. per sq. in. In the overlapping power field these "high pressures" become low pressures. Now, an examination of steam pressures and their utilization immediately suggests three definite groups, all covered by existing words which provide the needed standardization clarity. These are (a) *low* pressure, 10 lb. per sq. in. or less, (b) *process* pressures, 10 to 125 lb. per sq. in., and (c) *high* pressures, 125 lb. per sq. in. or more.

"Vacuum" and "Vapor" Systems

Names of heating systems need further classification. Mr. Lewis defines a vacuum system as "Any steam heating system which uses *thermotraps* and a pump." It is believed that this can be improved upon. In the first place, the pump is the basic essential to determination of a vacuum system and the trap's function is supplementary to the pump. Essentially, a vacuum heating system is a steam heating system in which a pressure below atmosphere is obtained and maintained in the return piping by use of power-driven, vacuum-creating equipment such as vacuum pumps.

Mr. Lewis admits and approves the term "vapor," but anyone coming to the heating industry from outside is almost sure to be struck by the incongruity of this meaningless and misapplied word.

What is vapor? The standard dictionary gives the Greek origin of the word to mean "to smoke" or "to breath forth" and defines vapor as "Any visible diffused substance floating in the air and impairing its transparency." In the field of physics, vapor is defined as "Any substance in a gaseous state with reference to the liquid or solid form; a gaseous liquid or solid; a gaseous substance which is at a temperature *below* its critical point and therefore regulated by pressure alone." Nicholson defines vapor as any substance in the gaseous condition at the maximum of density consistent with that condition.

It is in recognition of these conditions that some system manufacturers have avoided entirely the use of the term "vapor" in reference to two-pipe, low pressure open return line heating systems.

Traps and Trapping

Another subject to which Mr. Lewis has referred is traps. *Thermotrap* does not appeal because, as was stated above, it is undesirable to invent additional words in order to improve the nomenclature of an industry. Rather, the problem is to get some of the words used in a standardized manner and no word in the field of heating is so abused as "traps." We turn to the indexes of the trade publications and find such items as "traps, pressure," and "traps, vacuum." Can you trap a pressure or a vacuum? Mere asking of the question shows the inadequacy of the word as now used.

The word "trap" is derived from the earlier term "steam trap," a device to catch, stop or trap steam. It is unfortunate that the word "steam" has been dropped so generally, for practically all traps are truly steam traps.

Vague and confused as is the noun "trap," the depths are not reached until we consider its use in the heating industry as a verb. Here "to trap" no longer means to capture a wild animal, but to install a mechanical device called, or mis-called, a trap. Why not be consistent and "valve" a radiator, "strain" a strainer (install a dirt strainer)?

Admittedly, the word trap is too widely used and accepted to permit much change, but can we not perhaps give its present use a semblance of order?

Traps, that is, steam traps, may be classified by pressure, i.e., in the three pressure ranges already mentioned. Many traps, however, will operate in more than one of the three pressure ranges, the controlling fact being not

whether it is operated in atmospheric, low pressure, intermediate or process pressure, or high pressure, but simply the pressure difference at which it will operate.

A more promising basis for classifying traps is perhaps by the type of operating mechanism. Steam traps can be divided into two general classes, continuous and intermittent. These classes divide into thermostatic, float, bucket, tilting. Thermostatic traps are restricted to thermostatic operating means, i. e., by means sensitive to temperature. The simplest nomenclature would therefore seem to be the term "thermostatic traps" to be applied regardless of whether the traps are used with vacuum or open return line heating systems or in any other application.

Downfeed Risers and Food

There is another group of word practices which jar the ears of new arrivals in the heating industry. It is that group of words describing the various piping elements of a heating system, particularly "downfeed risers." A riser is something that rises, at least that is what one would expect. Feed has to do with food rather than with heating. In this particular connection simplified, better use of a few existing words will help more than addition of new words.

Mains and *branches* give the two basic words, although the distinction is never altogether clear; *supply* and *return* qualify them functionally. *Vertical* and *horizontal* describe the installed position. *Downflow* and *upflow* would be a big improvement.

Square Feet

Mr. Lewis makes a plea for elimination of the square foot. He refers to it as an obsolete term but we believe what he means is that it is an *obsolete unit of measure*. He wants to substitute for it those mysterious things, Btu's and pounds of steam. But we feel that he is over-optimistic. The demand for data in square feet grows daily. People want—and naturally—to *do more* and *to think less*. That is why simple—though inaccurate—units are daily preferred.—*Harold F. Marshall,* Advertising Manager, Warren Webster & Company.

Heat or Humidity

"It's not the Heat but the Humidity." Page 742, September, 1930, issue

I WAS rather interested in the short article on page 742 of the September issue. It occurs to me that the statement, "It's not the heat but the humidity," is rather misleading. As a matter of fact, it *is* the heat, for the wet bulb temperature is simply an indication of the total heat in the air, as you well know. Wouldn't it be more appropriate to say, "It's not the *temperature*, but the *heat*"?

The truth of this was brought to my notice very forcibly during the late weeks of last summer. In July and August temperatures of 102 or 103 were not uncommon in Kansas City, but as a usual thing, the wet bulb seldom exceeded 68 degrees. Early in September the maximum dry bulb ranged about 89, but wet bulbs of 76 were not uncommon. In the first instance the total heat in the air was approximately 31.8 Btu per pound, while in the second, it was about 38.7 Btu.

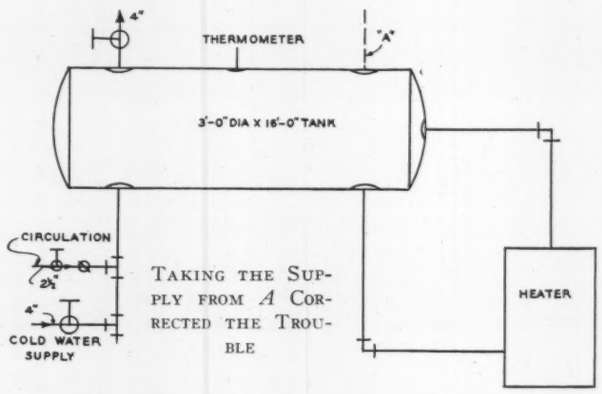
I believe that the paragraph which states that by regulating the moisture content so that it is low in a room with 80 deg. dry bulb and high in another room with 60 deg. dry bulb, people passing from one to the other wouldn't realize any difference of temperature, is open to question. It is true that the actual amount of heat in the rooms might be made the same, but it is certainly erroneous to neglect entirely the effect of heat transference due to temperature-head. Certainly, to make this statement literally true, air movement would also have to be given serious consideration. Unquestionably, also, the idiosyncratic tendency of the sweat glands to function at a higher or lower rate, due to the temperature encountered, thus providing either a deficiency or a superabundance of moisture to be evaporated, is also a very important consideration.

The problem is one that holds considerable interest, and while, unquestionably, the research laboratory of the *A. S. H. V. E.* has done remarkable work, there remains much yet to be done.—*Edgar S. Miller.*

Hot Water Storage Tank Connections Improved

The accompanying illustration indicates a 1,000 gallon hot water storage tank with a coal fired heater hooked up to it as installed in a boiler house of a factory community, which it supplied with domestic hot water.

From the time of its inception, the hot water system was the cause of complaints. The occupants of the dwellings supplied were troubled with rapid and apparently unreasonable fluctuations in the water temperature. A careful check-up of the thermostat controlling the heater damper, and the recording thermometer chart, failed to furnish a clue to the cause of the mystery.



TAKING THE SUPPLY FROM *A* CORRECTED THE TROUBLE

In a final attempt to correct the difficulty, it was decided to take the main supply from the tapping *A*. Much to our surprise and satisfaction this change entirely eliminated the troublesome condition.

It became apparent then that what had caused all the trouble was that when water was drawn during the "peak" period—that is, in the early morning, or at or around meal times—the make-up cold water supply entering immediately below the main hot water supply tapping, was carried, by virtue of its initial inertia, through the comparatively stagnant body of hot water in the tank, and into the system. When only comparatively little water was being used the small quantity of make-up was readily assimilated by the stored hot water.—*Henry G. Schaefer.*

INTERVIEWS OF INTEREST

Cold Water to Circulate Through Radiators in Summer

The building that has been designed to house the mechanical, electrical, chemical, and other engineering research of the A. O. Smith Corporation, Milwaukee, is undergoing serious inspection on the part of many architects and engineers during the process of its construction. It embodies many structural features never employed before and so many of its special details represent the outcome of separate technical studies that the entire building may well be regarded as a major project in research. It represents a flexibility in use that is a particular advantage in industries whose objectives undergo constant modification with the development of new demands and of new materials.

E. W. Burgess

Holabird and Root have designed the structure. Its engineering innovations are products of the A. O. Smith Corporation research staff. When built-up steel columns, hollow steel girders, and "battle deck" floors were determined upon, sections were made in strict accord with building specifications and subjected to extensive tests. The welded floor plates were made and welded, and fabrication routines fitted to the building scheme. Room size chambers, to parallel the spaces served, were employed in ventilation experiments. Fan volumes, air movement rates, cooling capacities; these are only a few of the independent studies undertaken preliminary to final plans.

The architects have followed no tradition in external features of the building plan. The activities that it houses are so new that the research plant in turn becomes a factory to produce the apparatus needed, but which is too advanced to be secured in the open market. Even the architectural form is new. Practically the entire outside walls are made of glass. There is a black stone base, with panel-like corners built up of Indiana limestone. Otherwise, the entire external expanse of the structure is plate glass set in aluminum, with strong vertical emphasis by means of ornamental aluminum pilasters that mark the positions of supporting columns. The plate glass front and sides are applied in V-shape bays twenty feet across, eight on the sides and six across the front. Strength and lightness are characteristic features of the plan.

It is a U-shaped building with 170 feet frontage, seven stories high. The 80 x 160 ft. space between the wings has been roofed over and equipped with a 20-ton crane to handle materials and apparatus. The early installation of this crane has speeded up construction work on the building itself. Future extension of both wings and crane way is possible.

The building, now nearing completion, will have a floor area of 224,050 sq. ft. and a volume of 3,749,650 cu. ft. Large open areas 45 by 185 ft. are available on every floor of each wing of the building, free from all obstructions. Head room of 14 feet is contemplated on all floors. No fixed partitions will be employed except for the entrance lobby, stairways, elevators, lockers, and toilet room enclosures.

All windows are sealed shut. Mechanical supply of air is made throughout, with all heating and air conditioning equipment housed in the basement and attic spaces. No ducts or unsightly piping are visible, and all electrical boxes and air registers are set flush with the walls.

E. W. Burgess, construction engineer for the A. O. Smith Corporation, in a special interview on the planning of this building, states that the structural steel features of the design are fundamental to the heating and air conditioning arrangements. Of chief importance in this connection he states that "the steel supports within the building consist of hollow columns 35 inches square with 20-ft. spacing center to center, and open truss type girders set in pairs. This results in manway space both vertically and horizontally throughout the finished building.

"The columns are built up around four 6 in x 6 in. angles, 35 in. back to back, set with plates on the sides, lattice bars on the outer face, and batten plates on inner face. Plates and girder joints are welded, and there are welded floors. These open passage ways everywhere provide ample means to conceal all piping, ducts, conduits, boxes, wiring, etc. All this equipment, that under usual conditions is exposed in engineering buildings, is concealed. The manways and ceiling spaces are accessible through doors on every floor, and work space there permits easy installation any time new piping or fittings may be called for.

New Building to House Research Activities of the A. O. Smith Corporation, Milwaukee

"In such a building there is no need upon first occupancy to try to anticipate any future piping or wiring needs, and our new building will carry no empty conduits to pay for and remain idle against some future contingency. The plans allow the introduction of 12-ft. pipe lengths into any hollow vertical column, and 7-ft. lengths can be passed and fitted horizontally at any column angle.

"The air supply has been calculated at 25 c.f.m. per person on the basis of 1,000 occupants. Humidity will range around 50 per cent in summer, but somewhat less in winter to prevent condensation on the glass outside walls. In order to maintain desired conditions independent of outside weather, winter and summer, the wall radiation on north and south exposures will serve a dual purpose of heating in summer and cooling in winter months. Cold water will be circulated at temperatures suited to produce a cooling around 10 deg. below outside temperatures in summer, with fans to diffuse the cooled air and prevent condensation on the piping.

"Since radiation requirements for cooling are higher than for heat by steam, the summer cooling units on the north and south exposures will probably be installed as a separate system to be heated by warm water at relatively low temperatures in winter months. Other heating will be by means of steam, two-pipe return, low temperatures. Steam comes into the building from a central power plant at 150 pounds pressure and is reduced within the building.

"Recirculation of air will be employed in offices of the several departments and in general rooms. No recirculation will be made in the chemical or mechanical laboratories. The chemical laboratories, housed on the sixth and seventh floors, will have a separate ventilation system. All hoods will have separate exhausts. There will be no mechanical possibility of fumes being turned back into the chemical or other departments.

"Detailed layouts are not yet worked out and the placing of apparatus is not fully determined upon, but the principles of control are pre-determined and tests are going forward on this basis. The diffuser unit to be used has been made of a new design. It supplies and exhausts the air at ceiling height. Ventilation air comes in at its periphery, and exhaust is made at the central part of the ceiling diffuser unit. Multiple units of this type will be so placed that any required subdivision of floor space by means of removable partitions can be undertaken without any possibility of cutting off the air supply to any of the sub-divisions."

Notwithstanding the elaborate research provision and the extremes of flexibility provided within these laboratories, the building represents true construction economy. The total weight of structural steel is only 3,667 tons. This is 1.96 lb. of structural steel per cubic foot of space, or 32.73 lb. of steel per square foot of floor space within the building. The dead weight per supporting column is 100,000 lb. less than the load represented by the usual type of steel joist and concrete slab construction, according to Mr. Burgess.

New Approach to Air Pollution Problems

There is in Cleveland at the Baldwin filtration plant a research laboratory whose activities afford a new perspective in a wide range of smoke abatement problems. Supported by the city of Cleveland and directed by Dr. R. D. MacLaurin, commissioner of trade waste, the evidence is here that in at least one community there is no bland belief in blanket ordinances that aim to secure unpolluted air by legislation. The keynote in Cleveland is investigative work with separate rulings wherever they are called for to fit the industry, the time, the place.

Dr. R. D. MacLaurin at Work in His Research Laboratory

The smoke laboratory is set up on a commercial scale for smoke collecting. Special apparatus has been developed of a type designed to collect smoke at its source in various manufacturing processes. Laboratory installations for smoke collecting studies permit the formation and collection of smoke clouds of any type, density, or size of particles. Tests on the quantitative collecting efficiencies and durability of filtering fabrics are made with various smokes, thereby resulting in the accumulation of data which may be applied in rational, economic and effective measures of smoke abatement. This is the only laboratory of its kind in the United States. The work is fundamental.

"Smoke abatement anywhere is a research problem," declares Dr. MacLaurin. "It is not merely a problem of rule-of-thumb control but rather a definite research to find some suitable, cheap and serviceable manner by which smoke, fumes and dusts can be collected.

"Our initial concern in laboratory investigation is to devise new measures for smoke recovery. To

clean air after it has been polluted is a secondary consideration.

"Our studies, then, have covered electrical precipitation of smokes, centrifugal methods, water washing, and bag filtration. A wide range of data are available at the laboratory on all these subjects. Several studies have been published.

"We have studied various types of dust: Dusts that damage property, that disintegrate metals and building materials, that have immediate or remote effects upon health, and that have recoverable value.

"Microscopic smoke particles ranging from 0.1 to 1.5 microns in size constitute the most serious phase of atmospheric pollution as they remain in suspension and consequently cause property damage by impingment and when inhaled cause injury to health. The larger particles which settle out of the atmosphere have been termed soot-fall.

"Soot-fall in terms of tons per square mile has been the yard-stick to measure the effectiveness of so-called smoke abatement laws. An investigation employing such a yard-stick for 1912-13 gave 937.8 tons per square mile in Pittsburgh. After ten years' enforcement of the standard smoke ordinance, in 1923-24 atmospheric pollution had increased to 1304.4 tons per square mile, though better furnaces and improved combustion methods had been in effect.

"Consequently there is little justification for making tar in smoke the sole index of 'good' or 'bad' chimneys. Coke, silica, iron oxide and sulphur acids may be much more excessive in the so-called 'smokeless' flue.

"It should be obvious, therefore, that more intelligent methods of smoke abatement must be employed if progress is desired. With the latter thought in mind, we are conducting investigations using a fabric filter for collecting smoke which will withstand high temperatures. This method will obviate the necessity for installing gas-cooling equipment and also the sensible heat of the gas may be conserved when desirable.

"Up to the present moment, atmospheric pollution benefits from anti-smoke legislation have been slight either in America or Europe. Although we have nothing but praise for fuel conservation programs that aim to cut down the appearance of black smoke by good combustion, yet it should be recognized that conservation of fuel does not as a consequence abate atmospheric pollution. The scientific approach to air hygiene is through vigilance and precision work that fits apparatus for smoke collection according to the problem encountered, simple to operate and not too costly to be borne. These are the engineering objectives of our laboratory research."—*S. P. M.*

Registers Respond to "Deflector Treatment"

To get an exhaust pull through a supply outlet, and to have an exhaust register supply air, may be defined as an efficiency record of minus 100 per cent.

The writer has encountered both these paradoxes, and in each case the solution lay in the introduction of properly designed deflectors.

Exhaust Register Discharges Air

In one case, a furred ceiling space under the roof of an apartment house served as a plenum chamber for toilet exhaust gathered from masonry toilet stack shafts, in the walls of which the toilet exhaust registers (fitted with fire louvres) were set. The shafts opened into the ceiling space.

Notwithstanding the fact that a negative pressure existed in the ceiling, a peculiarly located beam and the inertia of the air moving toward the fan from shaft *A*, shown in Fig. 1, combined to cause the top floor register of stack *B* to discharge, instead of to exhaust air. Actual anemometer readings showed a velocity of 300 ft. per min. at the register—the normal exhaust velocity for the job! A deflector installed as indicated by the dotted line *X* brought the wayward register back into line.

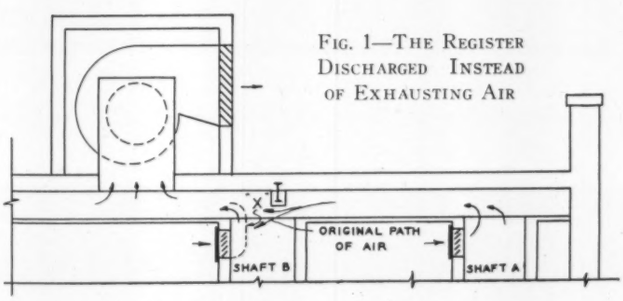


FIG. 1—THE REGISTER DISCHARGED INSTEAD OF EXHAUSTING AIR

Top Supply Register Refused to Emit Air

In the second case, a top supply register, with its duct taken from a side throat in a high velocity ceiling trunk supply duct immediately after an elbow, refused to emit air, but persisted in assuming the role of an exhaust register. (See Fig. 2.) The installation of the deflector *Y* remedied the difficulty. In this case as in the first, the inertia of the moving air caused the trouble. The tendency, of course, was for the air to continue moving in its initial direction. The heel of the main line elbow caused a change, but not rapidly nor completely enough to prevent the creation of a vacuum pocket roughly indicated by the line *Z*, within which the original throat was located.

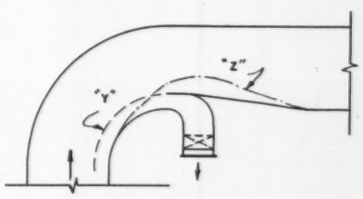


FIG. 2—A TOP SUPPLY REGISTER REFUSED TO EMIT AIR

The cases cited are, of course, extreme, but it is surprising how gratefully the individually "weak" register will respond to a judicious dose of "deflector treatment."—*Henry G. Schaefer.*

PRACTICAL PIPING PROBLEMS

How To Keep Hydraulic Equipment From Freezing

by **W. H. WILSON**

Protecting Hydraulic Machinery

Protecting hydraulic valves, piping and equipment from the damage caused by freezing weather is essential, not only on account of the delays and loss of production time while the piping is being repaired but the parts of the equipment that are usually damaged by freezing are expensive to repair and replace. Many times the parts that are damaged can not be repaired readily, as for example, large cylinders may have to be cast and then machined. Quite often this means a delay of weeks—sometimes months.

If the buildings where the hydraulic machinery is located are adequately heated at all times when the weather requires protection from freezing, it is of course not necessary to provide special heating for protecting the hydraulic machinery and no trouble should be experienced from the cold weather.

Hydraulic equipment and hydraulic systems of small size, not covering an extensive amount of ground, can, instead of using water for transmitting the hydraulic power, use oil or water diluted with some non-freezing liquid.

Conditions are different when the hydraulic pipe lines and hydraulic machinery are located in large forging shops or steel fabricating plants, where the buildings may not be equipped with heating systems. There is nearly always a certain amount of leakage that makes the use of oil and similar liquids expensive. The pits under the hydraulic machinery require attention to be kept clean and more labor is required to keep the pits clean when oil is used.

Different plants have different ways of taking care of the hydraulic equipment during the winter season, much depending on local conditions. In some cases, the hydraulic power is kept on the pipe lines and the maintenance force is sufficient to have the machinery operated frequently during freezing weather, outside of regular working hours, such as nights and holidays. Salamanders fired with coke or coal are placed near press cylinders, operating valves are covered in extremely cold weather, packing glands are sometimes loosened, as the wet packing freezing will push outward on the glands, straining and sometimes breaking the packing gland bolts.

When the hydraulic pressure is not maintained on the equipment, outside of the regular working hours, the piping system is blown out with compressed air at the close of the working hours; this will naturally aid materially in providing protection from freezing weather. It will be necessary, in this case, to provide some heat, such as salamanders, near the equipment, as it is practically impossible to remove all of the water from some of the cylinders and valves, without disconnecting and removing parts of the machinery and this would take too much time to replace to permit work the following day.

Plant officials, as a general rule, do not seem to take notice of the time spent in draining, blowing out, firing salamanders, distributing coal and coke, removing ashes, of the labor required on cold mornings, of placing lighted, oily waste on frozen valves, warming up lift cylinders, pipe connections and performing many other duties to get the hydraulic equipment started.

It is doubtful if these officials ever get accurate and correct statements showing the cost of maintaining hydraulic machinery, in this manner, during freezing weather, as this work is usually charged in various ways, according to routine rules of the plant, covered by the customary explanation, "account of freezing weather."

When steam is available for heating, it can be used to advantage and much of the labor eliminated that is required when salamanders and similar heaters are used.

The illustration shows a hydraulic press of the overhead or down-stroking type, equipped with a prefilling system. This type of press can be equipped with steam heating as shown. The different types of hydraulic machinery will require different arrangements and location of radiators and piping, as no set rule will apply to all types. The amount of heat required will depend entirely on local conditions. All the heat needed is just enough to keep the water in the cylinders, valves and piping above the freezing temperature. If the water in the cylinders and valves gets too warm, it will injure the leather packings.

Referring to the illustration, the following parts of the press should be protected from freezing: The lift cylinders and stripper cylinder located in the underground pit can be taken care of by steam heating pipe coils or radiators located on the walls of the pit, as shown at *S*. The operating valves, shown at *M*, can be protected by placing a radiator or pipe coil underneath the valves, as shown at *N*. The floor around the operating valves is usually removable and if not tight fitting, pieces of canvas or similar material may be laid over the openings, which will help to prevent heated air escaping. Sections of small radiators are fastened to the lower side of the upper platen, near the packing box glands of the main cylinders, as shown at *H* and the return pipe from these radiators is brought down alongside of the hydraulic supply pipe to the main cylinders. Both pipes are insulated together so that the heat from the return pipe will protect the hydraulic supply pipe, *E*. A section of wall radiation *D*, is placed under the filling check valve, *B* and the return pipe *F* from the opposite end of this radiator is brought down alongside of the small hydraulic pipe, *G*. This pipe is used to operate the filling check valve, both of these pipes being insulated together. The insulation is not shown in the illustration.

This small hydraulic pipe is usually the one that causes the most trouble in extreme cold weather. It is not unusual for this pipe to freeze when the press is in operation, if the press is located in a place subject to drafts of cold air.

The tank on top of the press holding the water used in pre-filling, shown at *A*, is heated by circulating the water, similar to the way overhead sprinkler tanks, used in connection with fire protection systems, are heated.

The heater is made by welding a pipe sleeve over a section of the steam supply pipe. In this case it is placed on the supply to the radiator under the filling check valve. The size of this supply pipe would ordinarily be 1 in or 1¼ in., and a piece of 2-in. pipe can be used for the sleeve. A 1-in. coupling is welded on the top of the sleeve for the flow pipe, and a similar coupling is welded on the bottom of the sleeve for the return, as shown by the detailed sketch.

The return pipe is tapped at the lowest point of the pre-fill water, when the press is not in operation, which in this case is the lower side of the elbow on the low pressure side or inlet of the filling check valve, and the flow pipe is connected to the pipe leading from the filling check valve to the tank. This will allow the water to circulate and be heated when it is very low in the tank. The length of the sleeve for the heater will depend on the size of the pre-fill tank and local weather conditions. Usually a heater 18 in. long will be sufficient. The heater is shown in the illustration at *C*.

The exhaust or discharge pipe, *L*, from the hydraulic operating valve, *M*, which has only the pressure of the height of the water that may be in this pipe, is heated in a similar manner by the heater, *O*, as shown on the supply pipe to the radiator, *N*. The flow pipe is connected a short distance above the floor line, as the discharge pipe may be at times only partly filled with water. The heating of the contents of this pipe should be carefully considered, as a frozen discharge pipe will prevent a release of water when the press is being operated, which will allow the hydraulic pressure to accumulate in this pipe, which is usually of standard weight. A ruptured pipe may be the result.

The tank overflow pipe, *T*, if it has a gravity flow to the main return lines and pumping equipment, should not require a heater. In case this pipe is trapped, a heater of the type described should be installed and the contents of this pipe heated similar to the discharge pipe, *L*.

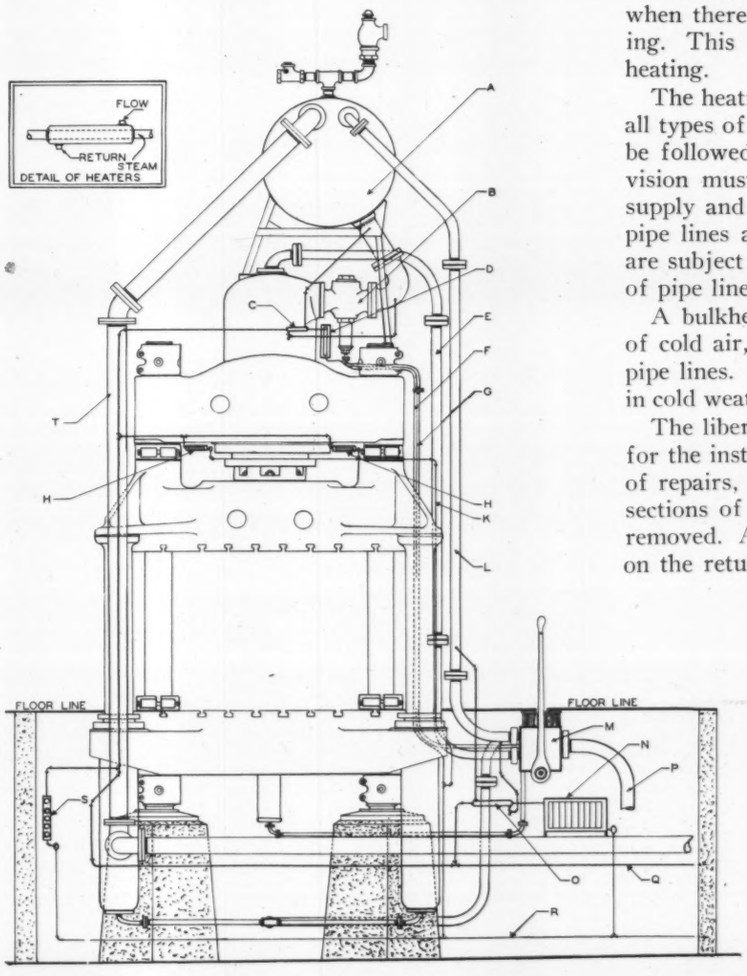
The heating of the press can be further improved to effect economy in heating by providing a cover of canvas or other suitable material and covering the entire top of the press down to the upper platen, during the heating season. By having a main steam heating supply valve located conveniently for operation, the heating system can be easily turned off in mild weather and turned on when there is danger of the hydraulic equipment freezing. This will effect a saving in the steam used for heating.

The heating system described will not be applicable for all types of hydraulic machinery but the general plan can be followed, where steam is available for heating. Provision must be made also for protecting the hydraulic supply and return lines leading to the press pits. These pipe lines are usually located in tunnels. Some tunnels are subject to drafts of cold air, which may be the cause of pipe lines freezing.

A bulkhead, placed across a tunnel to break the flow of cold air, in some cases will afford protection for the pipe lines. Trap doors carelessly left open cause trouble in cold weather.

The liberal use of unions and flanges is recommended for the installation of the heating system piping. In case of repairs, repacking and adjustments of the machinery, sections of the heating piping can be easily and quickly removed. A tee with the lower opening plugged is used on the return connections for the heaters, in order that they may be drained to remove accumulations of sediment.

When steam is not available for heating, a direct fired heater, using coal, oil, or gas may be used, and the heated air, by a system of blow pipes, discharged so as to come in contact with the parts requiring protection, as shown.

The adequate heating of hydraulic equipment will be repaid in the amount of time saved from delays to production work, labor costs of idle employes waiting to commence work and less money paid for expensive repairs and replacement costs.

ILLUSTRATING THE WAY TO PROTECT HYDRAULIC PRESSES FROM FREEZING